12/4-23-91 JS ①

ANL/EAIS/TM-35

Sectoral Electricity and Fossil Fuel Demand in U.S. Manufacturing: Development of the Industrial Regional Activity and Energy Demand (INRAD) Model

Environmental Assessment and Information Sciences Division
Argonne National Laboratory

Operated by The University of Chicago,
under Contract W-31-109-Eng-38, for the
United States Department of Energy

Argonne National Laboratory

Argonne National Laboratory, with facilities in the states of Illinois and Idaho, is owned by the United States government, and operated by the University of Chicago under the provisions of a contract with the Department of Energy.

This technical memo is a product of Argonne's Environmental Assessment and Information Sciences (EAIS) Division. For information on the division's scientific and engineering activities, contact:

Director, Environmental Assessment and
Information Sciences Division
Argonne National Laboratory
Argonne, Illinois 60439-4815
Telephone (708) 972-3759

Presented in this technical memo are preliminary results of ongoing work or work that is more limited in scope and depth than that described in formal reports issued by the EAIS Division.

Disclaimer

Reproduced from the best available copy. Available from the National Technical Information Service (NTIS), U.S. Department of Commerce, 5285 Port Royal Road, Springfield, Virginia 22161.

NTIS price codes:
Printed copy A05
Microfiche A01

ANL/EAIS/TM--35

DE91 010682

ANL/EAIS/TM-35

Sectoral Electricity and Fossil Fuel Demand in U.S. Manufacturing: Development of the Industrial Regional Activity and Energy Demand (INRAD) Model

by G.A. Boyd, E.C. Kokkelenberg,* and M.H. Ross*

Policy and Economic Analysis Group,
Environmental Assessment and Information Sciences Division,
Argonne National Laboratory, 9700 South Cass Avenue, Argonne, Illinois 60439

February 1990 (published March 1991)

Work sponsored by United States Department of Energy,
Assistant Secretary for Fossil Energy, Office of Planning and Environment

Report prepared for the National Acid Precipitation Assessment Program

MASTER

---

*Kokkelenberg is affiliated with the Department of Agricultural Economics at Cornell University and the State University of New York, Binghamton, and Ross is affiliated with the Department of Physics, University of Michigan, Ann Arbor.

Contents

Contents (Cont'd)

Tables

Figures

Sectoral Electricity and Fossil Fuel Demand in U.S. Manufacturing: Development of the Industrial Regional Activity and Energy Demand (INRAD) Model

by

G.A. Boyd, E.C. Kokkelenberg, and M.H. Ross

Abstract

This report describes the modeling approach, data sources, and procedures used to estimate and forecast electricity and fossil fuel use in U.S. manufacturing. The forecasts are required by several models in the Emissions and Control Cost Integrated Model Set (ECIMS) used by the National Acid Precipitation Assessment Program (NAPAP). The theoretical approach used to develop the Industrial Regional Activity and Energy Demand (INRAD) model combines statistically estimated energy demand equations with forecasts of industrial activity, energy prices, technology penetration, and state-level benchmarks to compute state-specific and industry-specific forecasts of electricity and fossil fuel demand. These INRAD forecasts, in turn, drive the model of utility electricity generation and, after further disaggregation, the models of industrial emissions due to fossil fuel use. The model for estimating energy demand equations is based on the generalized Leontief functional form, with factor-biased technical change and constant returns to scale imposed. The assumption to model fossil fuel and electricity use jointly is supported by statistical estimates. Separate demand equations are estimated only for energy-intensive industries or subsectors.

1 Introduction

This report describes the Industrial Regional Activity and Energy Demand (INRAD) forecasting model. INRAD is an econometrically based model that predicts energy demand. It is the basis for the industrial electricity and fossil fuel demand forecasts that drive the Emissions and Control Integrated Model Set (ECIMS) used in the National Acid Precipitation Assessment Program (NAPAP). Specifically, INRAD provides data on the growth rate in industrial electricity demand that are input into the model of the utility sector, the Advanced Utility Simulation Model (AUSM), and it provides forecast data on fossil fuel demand that are input into the industrial boiler and process models, Industrial Combustion Emissions (ICE) and Process Model Projection Technique (PROMPT). These three models -- AUSM, ICE, and PROMPT -- are part of the ECIMS (Fig. 1).

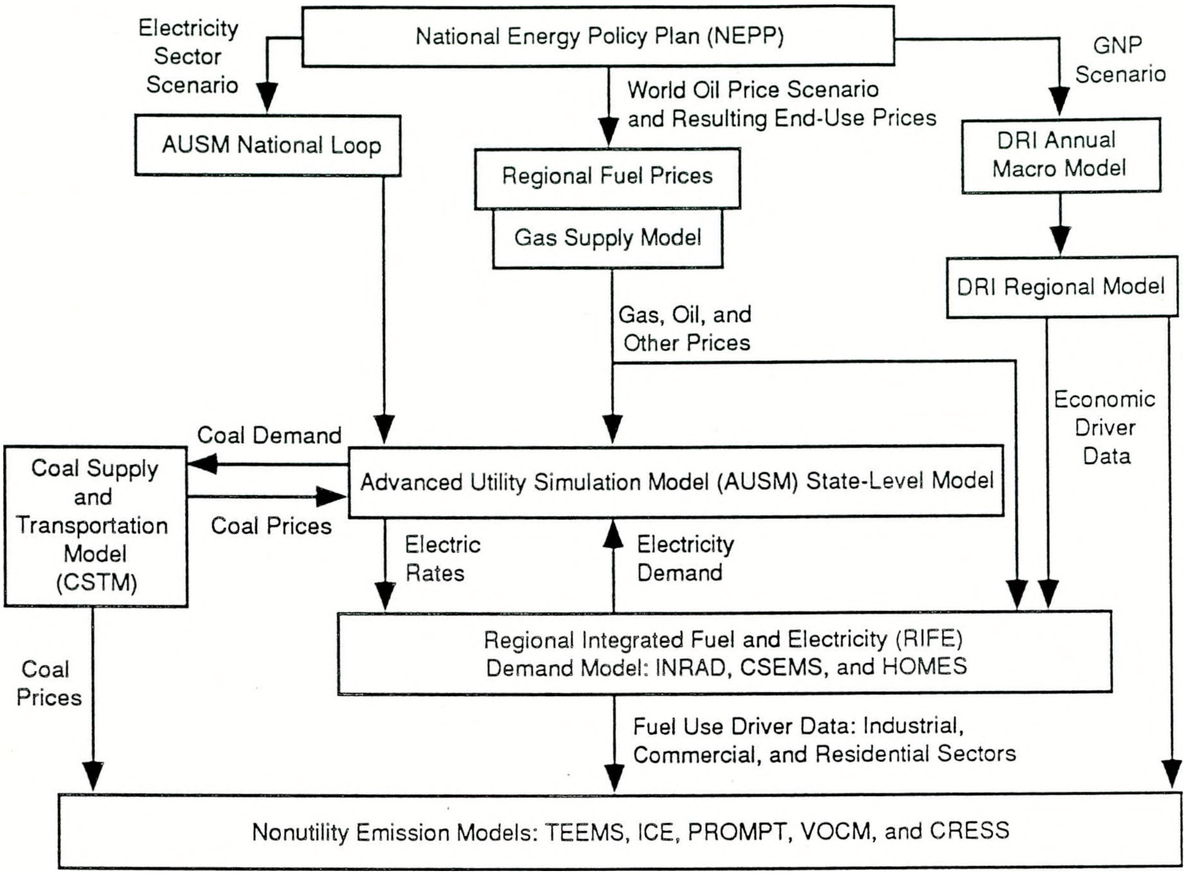

FIGURE 1 Overview of the Emissions and Control Cost Integrated Model Set

The organization of this report is as follows. The theoretical basis of the INRAD national equations is discussed in Sec. 2. Descriptions of the data sources and the estimation techniques are presented in Secs. 3 and 4. Section 5 presents supplemental forecasts and bridge equations between the Data Resources, Inc. (DRI) annual macroeconomic model and the INRAD model. Section 6 briefly describes the implementation of the state-level model code in the ECIMS, some of the INRAD model testing, and the relationship between INRAD and the ICE and PROMPT models. Section 7 discusses INRAD's estimates and interprets its key parameters. Section 8 presents the data from several INRAD runs that were used as input for the ICE and PROMPT models and their resultant emission estimates. The runs were done for four scenarios: a reference case, a lower economic growth scenario, a higher conservation scenario, and a lower oil and gas price scenario. Appendix A contains computer printouts with more detailed data on emissions, costs, and fossil fuel demand for ICE. Detailed emissions data for PROMPT are provided in Appendix B.

2 Theoretical Modeling Approach

A theoretical model was developed to predict how future energy use will be influenced by changes in energy prices and the general level of economic activity. This model was tested using historical sector-specific data, and values for the parameters of interest were estimated. These estimated parameters were then used in a simulation study to assess how changes in prices and sector-specific technologies would affect energy demand.

The theoretical model is based on the assumption that a general recipe exists for every production process, including manufacturing, which is the focus of this report. Economists call this recipe a production function. Such a general production function (F) shows the relationship between the ingredients (or inputs, X) and the product (or output, Q). The general production function can be expressed as follows:

$$Q_t = F\ (X_t\ T_t) \tag{2.1}$$

where:

Q = output,

t = unit of time,

F = general production function,

X = a vector of inputs such that $X' = X_1, X_i, ..., X_n$ where a prime denotes the transpose and i = ith input, and

T = technological level.

Because each production process is assumed to involve resource costs, a cost function (G) is associated with each production function (F). The cost function can be expressed as follows:

$$C = G\ (Q_t\ P_t\ T_t) \tag{2.2}$$

where:

C = total cost,

G = cost function, and

P = a vector of input prices such that $P' = p_1, p_2, ..., p_n]$.

Economic theory has shown that under certain conditions, the optimal (cost-minimizing) demands by firms for the flow of inputs can be derived from either the production function or the cost function. The approach selected depends on the tractability of the specific functional form that the general relationship of Eqs. 2.1 and 2.2 takes as well as a wide range of other assumptions.

Because energy usage per unit of output is the parameter of interest, a functional form amenable to this parameter was chosen. The functional form was also selected to be consistent with the engineering notion that a fixed set of technological relationships exists among inputs at any given time. The form chosen was a Leontief* production or cost function. However, this particular functional form was found to be too restrictive for the parameters being modeled by INRAD, because it does not allow for any substitution or conservation of production factor inputs (X) as a response to price changes. Therefore, an extension of the cost function that is dual to the Leontief production function is employed in the theoretical model.

2.1 Generalized Leontief Function

The generalized Leontief function was developed by Diewert (1971) and is a so-called flexible functional form, which allows the elasticities of substitution and scale to change with output or factor proportions. These flexible functional forms can be considered as either exact cost or production functions or approximations of such functions, specifically as a Taylor series expansion limited to the first two derivatives.** The generalized Leontief cost function (C) has the following form:

$$C = h(Q) \Sigma_i \Sigma_j b_{ij} p_i^{1/2} p_j^{1/2} \tag{2.3}$$

where:

$h(Q)$ = a nondecreasing, homothetic transformation function on output Q,

b = parameter to be estimated,

i, j = indexes of production factor input, and

p = input price.

The transformation of output, h(Q), has taken a variety of forms in the literature. The simplest is that of $h(Q) = Q$, which leads to constant returns to scale with no technical progress. A more

---

*Named after Wassily Leontief, who developed input-output analysis (see Leontief 1941; 1947).

**The expansion is generally taken around the points $C(0) = 0$, $h(Q = 0) = 0$, $P(0) = 0$; however, this need not be so.

complex form is suggested by Diewert and Wales (1987); it allows for nonhomothetic scale effects and nonneutral technological change, as demonstrated in the following equation:

$$
\begin{aligned}
C(P,\ Q,\ T) = {} & Q \sum_{i=1}^{n} \ Q \sum_{j=1}^{n} b_{ij}\ (p_i p_j)^{1/2} \\
& + Q\ t \sum_{i=1}^{n} b_{it}\ p_i + b_t \left(\sum_{i=1}^{n} \alpha_i\ p_i \right) T \\
& + b_{qq} \left(\sum_{i=1}^{n} \beta_i\ p_i \right) Q^2 + b_{tt} \left(\sum_{i=1}^{n} \gamma_i\ p_i \right) T^2\ Q
\end{aligned}
\tag{2.4}
$$

where:

α, β, γ = vectors of parameters to be estimated.

Diewert and Wales set the three N numbers α_i, β_i, and γ_i as constants and thus specify a whole family of flexible functional forms or generalized Leontief forms. They also allow the technological level (T) to be proxied by time (t).

Another form for variable return to scales is the following:

$$
C(Q,\ P) = Q \sum_{i=1}^{n} \sum_{j=1}^{n} b_{ij}\ p_i^{1/2}\ p_j^{1/2} + Q^2 \sum_{i=1}^{n} b_i\ p_i + \sum_{i=1}^{n} \beta_i\ p_i \tag{2.5}
$$

The significance of this form is that it expands Eq. 2.3 (the original Diewert form), allowing more flexibility in parameters. This flexibility is needed by the theoretical model to explore technological change and (later) nonconstant returns to scale.

2.2 Selected Functional Form

The functional form selected for use in this study represents the production function as follows:

$$
Q = F\ (K,\ L,\ E,\ F,\ M,\ U,\ T) \tag{2.6}
$$

where:

K = capital services,

L = flow of labor,

E = electricity,

F = fossil fuel,

M = intermediate materials, and

U = capacity utilization rate.

This production function includes a nonstandard element, the capacity utilization rate (U). Such production functions, however, are theoretically correct only in those cases involving disequilibrium models (i.e., models in which the firm is not on the production frontier). The generalized Leontief form is consistent with a long-run equilibrium model of the production process. Because the industrial sector underwent several price and market shocks over the period being modeled, a disequilibrium model is appropriate. In fact, a family of such models can be distinguished by varying the capacity utilization rate. The inclusion of this capacity utilization parameter is thus an expedient way to single out one model in this family. In the theoretical model described here, the output is the result of a flow of inputs, given a capacity utilization rate and a technology. The specific version of the generalized Leontief form used in the theoretical model is written as follows:

$$C(Q, P, Z) = Q\left[\sum_{i=1}^{n} \sum_{j=1}^{n} \alpha_{ij}\, p_i^{1/2}\, p_j^{1/2} + \sum_{i=1}^{n} \sum_{k=1}^{m} \gamma_{ik}\, p_i\, Z_k\right] \tag{2.7}$$

where:

Z = a vector of m additional variables used to predict factor intensities;

i = E or F;

j = all production factor inputs: K, L, E, F, and M;

k = D3, D4, U, DT, or T;

D3 = dummy for 1973;

D4 = dummy for 1974 (the OPEC embargo); and

DT = industry-specific technological change.

Optimal demand is then represented (according to Shephard's Lemma) as follows:

$$X_i^* = \partial C/\partial p_i$$
$$= Q \sum_{j=1}^{n} \alpha_{ij} \, (p_j/p_i)^{1/2} + Q \sum_{k=1}^{m} \gamma_k \, Z_k \qquad (2.8)$$

where:

X_i^* = *i*th input demand.

Because the focus of the theoretical model is on energy-intensity functions, Q is moved to the left side of the equation and a function that is linear in variables as well as in parameters is estimated. Furthermore, the form is limited to equations for purchased electricity and for fossil fuels. Specifically, these are as follows:

$$E/Q = a_{EE} + \sum_{j\neq E}^{n} a_{Ej}(p_j/p_E)^{1/2} + \gamma_{ED3}D3 + \gamma_{ED4}D4 + \gamma_{EU}U + \gamma_{EDT}DT + \gamma_{ET}T \qquad (2.9)$$

$$F/Q = a_{FF} + \sum_{j\neq F}^{n} a_{Fj}(p_j/p_F)^{1/2} + \gamma_{FD3}D3 + \gamma_{FD4}D4 + \gamma_{FU}U + \gamma_{FDT}DT + \gamma_{FT}T \qquad (2.10)$$

Like Diewert's form, this form assumes symmetry, in that $a_{FE} = a_{EF}$. The additional variables (*Z*) used to predict the factor intensities include capacity utilization rate (U) and two alternative specifications for technical change -- industry-specific technological change (DT) and level of technology (T).

Level of technology is measured by accumulated intensity, and in two cases, it is measured by the penetration of specific electricity-using technologies, i.e., electric arc furnaces in the steel-making industry and thermomechanical pulping in the paper industry. For all industries, the term T is used to estimate exogenous, factor-biased levels of technology and is defined as a declining sum of past energy intensities. Thus, recent experience is more heavily weighed than past experience, as represented by this formula:

$$T_{it} = [T_{i,t-1} + (X_{i,t-1}/Q_{t-1})] \; / \; (1 + \mu t) \qquad (2.11)$$

where μ = an industry-specific parameter (here set at 0.5 at zero; in subsequent work, this parameter will be estimated).

This formulation of technological changes, which is based on the work of Walfridson (1987), allows the estimated coefficient to approximate either a declining or a constant exponential growth rate. The numerator treats technological change as a function of the sum of either historical energy intensity or energy requirements per unit of output. By including capacity utilization effects, the theoretical model departs from the theoretical basis of duality and cost function analysis. Although its treatment is ad hoc, it controls for the effects of recessions. Without this variable, the price responses would most likely be biased.

To introduce a dynamic element into the model, a four-year moving average was used to calculate energy prices. The original idea was to model the impact of prices by using a four-year equally weighted price. This method was intended to accommodate for the ability of firms to smooth out price fluctuations through contracts and other measures as well as to recognize any turns in the price series. The average would also mitigate any randomness in the data. A moving average is a linear time-invariant filter. Later in this report, when the models are estimated using an autoregressive structure, this procedure is again a case of applying a filter via the partial differencing operation. This two-filter procedure has been known to introduce specious cyclical behavior, which is known as the Yule-Slutsky effect. (See page 81 of Harvey [1987] for a discussion of this problem.) Thus, in effect, some of the theoretical model's results reported on here may have been influenced by the way that the data were treated. This issue will be tested in future analyses.

The present analysis focuses on key energy-using industries rather than on industry as a whole. Accordingly, a separate set of equations was estimated for eight energy-intensive industry groups (see Table 1). These eight groups were derived from seven energy-intensive industries as defined by a two-digit Standard Industrial Classification (SIC) code. Only the energy-intensive, basic materials portion of the two-digit sector was used. A single set of equations was estimated for all other non-energy-intensive industries (NEIs), including the downstream product portions of the seven two-digit industries in Table 1. A discussion of issues related to energy-intensive industries and upstream versus downstream production trends can be found in Boyd et al. (1990).

TABLE 1 Energy-Intensive Industry Groups

SIC Code[a]	Industry Description	NEA Sector[b]
20	Food	14000
22	Textiles	16000, 17000
26U	Basic paper	24020, 24990a
28U	Organics	27010a
	Inorganics	27010b
	Fertilizers	27020
	Plastics and synthetics	28010, 28020, 28990
29U	Petroleum refining	31011
32	Glass and glass products	35000
	Cement	36010
	Stone and clay products	36990
33FE	Ferrous metals (iron and steel)	37011, 37012, 37990
33AL	Primary aluminum	38040

[a] A number alone indicates that INRAD uses the entire two-digit SIC industry; a U indicates that it uses only the upstream product sector.

[b] These codes are from the National Energy Accounts (NEA) industry taxonomy listing (Jack Faucett Associates 1984). An "a" or "b" indicates that additional disaggregation was performed by Argonne National Laboratory.

3 Input Data for INRAD

The data used as input to the INRAD model are national in scope and cover the period from 1958 through 1985. They are derived from observations of the industrial sector as represented by SIC codes 20 through 39. Several sectors are subdivided into upstream or downstream (finished product) subsectors (see Table 1). Data on sector-specific output (i.e., shipments), fossil fuel use, electricity purchases, and capacity utilization are used. Industry (by two-digit SIC code) average prices for each energy source are used to derive industry-specific fossil fuel aggregate prices and electricity prices. National price indexes for labor, capital, and intermediate materials are also used.

3.1 Sources and Characteristics

Descriptions of each input variable and its source are provided in this section. Five price inputs (electricity, fossil fuels, labor, materials, and capital) are used by the model to make estimates. The characteristics of the input price data are presented in Table 2. The characteristics of the input data on output (i.e., shipments of fuel), fossil fuel and electricity consumption, and technological change are presented in Table 3.

3.1.1 Price of Electricity

The price of electricity (P_E) is a four-year moving average of past (t, t - 1, t - 2, and t - 3) energy prices (in dollars per Btu) deflated by the implicit Gross National Product (GNP) price deflator. Because the data from the National Energy Accounts (NEA) in the U.S. Department of Commerce (Jack Faucett Associates 1984) contained some errors for the years 1961-1967, a national average correction factor was developed by comparing data on electricity prices from the national census of manufacturing industry with NEA's total industry data. This correction factor was applied to the industry-specific series to maintain the differences in the level of industry-specific electric rates.

3.1.2 Price of Fossil Fuels

The price of fossil fuels (P_{F12}) is also a four-year moving average of past (t, t - 1, t - 2, and t - 3) fossil fuel energy prices from the NEA (Jack Faucett Associates 1984). The fossil fuel price index is defined as the sum of all fossil fuel expenditures divided by the quantity of energy for each industrial sector (in Btu). The units are in dollars per million Btu and are deflated by the implicit GNP price deflator.

TABLE 2 Summary Statistics for Input on Prices ($\$/10^3$ Btu)

Price Variable	SIC Code	Mean	Minimum	Maximum	Variance
Fossil fuel (P_F)	20	1.91	1.03	3.72	0.94
	26	1.93	1.03	3.57	0.86
	28	1.83	1.00	3.62	0.88
	29	1.94	1.00	4.07	1.24
	32	1.77	1.00	3.29	0.67
	33	1.88	1.00	3.75	0.94
	Other[a]	2.09	1.10	4.13	1.16
Electricity (P_E)	All	10.04	7.14	14.55	5.09
Materials (P_M)[b]	All	0.97	0.87	1.06	0.00
Capital (P_K)[c]	All	0.17	0.15	0.19	0.00
Labor (P_L)[b]	All	1.53	1.48	1.61	0.00

[a] This price series was used for estimating SIC 22.

[b] 1980 index = 1.0.

[c] After-tax interest rate (i.e., 0.167 = 16.7% interest).

3.1.3 Price of Labor

The price of labor (P_L) is an aggregate index of labor cost as used in the Data Resources, Inc. (DRI) annual macroeconomic model.

3.1.4 Price of Materials

The price of materials (P_M) is defined as the aggregate producer price index (minus energy and related products) as used in the DRI annual macroeconomic model.

3.1.5 Price of Capital

The price of capital (P_K) is defined as the stock-weighted average of DRI's capital rental-price series. The three components are durables, structures, and public utilities.

3.1.6 Capacity Utilization Rate

The capacity utilization rate (U) is expressed as a decimal percent. The source of the data was the Board of Governors of the Federal Reserve System (Federal Reserve Bulletin various dates). Different series cover SICs 22, 26, 28, 32, 33, and the total industrial sector.

TABLE 3 Summary Statistics for Input on Industrial Energy Shipments and Consumption

SIC Code[a]	Industry Description	Variable[b]	Mean	Minimum	Maximum	Variance
20	Food	F	775	679	925	4,282
		E	109	53	157	1,177
		Q	1,117,524	777,788	1,477,658	45,457,603,349
22	Textiles	F	212	167	260	696
		E	74	39	96	368
		Q	242,652	138,560	317,337	3,230,254,746
26U	Upstream paper	F	935	695	1,114	14,002
		E	103	37	163	1,752
		Q	115,837	67,578	172,173	854,542,932
28U	Upstream chemicals	F	1,732	1,043	2,308	106,907
		E	340	259	449	4,033
		Q	275,969	121,714	397,586	7,533,585,926
32	Glass, cement, stone, and clay	F	1,048	794	1,224	15,377
		E	83	41	113	500
		Q	194,862	129,160	245,315	102,276,910
33FE	Ferrous metals	F	2,755	1,586	3,444	291,163
		E	186	86	272	2,935
		Q	330,008	216,294	454,954	3,925,315,786
33AL	Aluminum	F	145	29	215	3,114
		E	178	80	262	3,051
		Q	16,132	7,709	22,837	22,071,050

[a] U = upstream sector of corresponding industry; FE = ferrous metals and AL = aluminum, two sectors of the primary metals industry.

[b] F = fossil fuel consumption (10^{12} Btu); E = electricity purchases (10^{12} Btu); and Q = output (10^3 1980 $).

3.1.7 Output or Shipments

Output (Q) is defined as shipments adjusted for inventory changes. Data (see Table 3) are given in thousands of U.S. dollars, deflated by the output price deflator developed by the Bureau of Labor Statistics (BLS). The source for the data was *Manufacturer's Shipments, New Order and Inventories [M3], Current Industrial Reports* published by the U.S. Bureau of the Census (BLS various dates).

3.1.8 Fossil Fuel Consumption

Fossil fuel (AF) is defined as the total annual consumption of coal, coke, gases, and hydrocarbon liquids (in Btu). By-product biomass fuels are not included. The total fossil fuel data are in given in millions of Btu per year. The source was NEA (Jack Faucett Associates 1984).

3.1.9 Electricity Purchases

Electricity (AE) refers to annual electricity purchases. The data are given in millions of Btu per year (conversion factor is 3,413 Btu = 1 kilowatt-hour). The source was NEA (Jack Faucett Associates 1984).

3.1.10 Technological Changes

Two types of technological change are accounted for in the model estimates. The first is engineering-oriented change based on industry-specific data about major process changes in the upstream portions of the paper (SIC 26) and primary metals (SIC 33) industries. These industry-specific technological changes (TD) are the use of thermomechanical pulping (TMP) in SIC 26 and electric arc furnaces (EAFs) in SIC 33. The second change is the more traditional economic measure of exogenous, factor-biased technological change (T). The sources of these data were the U.S. paper and steel trade associations, which estimate trends based on historical energy output ratios (American Paper Institute 1988; American Iron and Steel Institute 1988).

The engineering definition of technological change is based on changes in some major process variable that would cause an industry to switch the type of fuel it uses. The variable is expressed as a percent of the (engineering-feasible) maximum share of production. In the case reported on here, the process variables are TMP and EAF, both of which cause a switch from fossil fuel to electricity. Exogenous, factor-biased technological change for all industries is defined as a declining sum of past energy intensities, as expressed by Eq. 2.11.

3.2 Level of Sectoral Disaggregation

The sectoral aggregation level used by INRAD is based on several factors. The final choice represents a compromise among modeling requirements, data availability, economic theory, engineering considerations, and time and budget constraints.

3.2.1 Modeling Requirements

Within the ECIMS, INRAD must provide state-level forecasts of total industrial electricity demand for the AUSM model, and it must provide forecasts of industry-specific boiler fossil fuel demand in SICs 20 (food), 22 (textiles), 26 (paper), 28 (chemicals), 33 (primary metals), and the "other" category (NEI industries) for the ICE model.

3.2.2 Level of Available Data

Industry-specific, state-level data are available from the U.S. Bureau of the Census, but several problems are involved with the use of these data. First, the time period extends only to 1981. Second, at the two-digit SIC level required by the ICE model, the census data are often censored to maintain confidentiality. For many industries, this censoring is even worse for data at levels more specific than the two-digit level. National data up to 1985 from BLS and NEA have a high degree of sectoral detail with respect to industrial output, energy use, labor, and materials.

3.2.3 Economic Theory Recommendations

Economic theory suggests that production and cost function approaches be based on homogenous industry output. However, most two-digit SICs do not conform to this assumption. Good examples are SIC 32 (glass, cement, stone, and clay) and SIC 28 (chemicals). In fact, one could argue that the regional industry mix is an important determinant of regional differences in energy-elasticity estimates for the total industry.

3.2.4 Engineering Considerations

There are significant engineering differences between the upstream processing of primary materials and the downstream finishing process (with its associated "value added"). Energy use is most closely related to the materials processing portion of the industrial sector. The energy-intensive industries singled out (see Table 1) by INRAD are SICs 20 (food), 22 (textiles), 26 (paper), 28 (chemicals), 32 (glass, cement, stone, and clay) and 33 (primary metals).* Although SICs 20 and 22 are not as energy intensive as the other industries, they are required by the ICE model. Although engineering and economic theories suggest that more disaggregation in INRAD would be desirable, only two industries are disaggregated into their upstream and downstream components: paper (SIC 26) and chemicals (SIC 28). Primary metals (SIC 33) is disaggregated into three sectors: ferrous metals (iron and steel), aluminum (SIC 3334 only), and other nonferrous metals (NEA 38990). The other nonferrous metals are consolidated into the NEI category. In addition, the iron and steel sector in SIC 33 is not subdivided into downstream and upstream components because essentially all of it is upstream. The requirement of a state-

---

*Petroleum refining (SIC 29) is also an energy-intensive industry, but all attempts to estimate parameters for this industry have failed. This failure is attributed to the difficulty of accurately measuring the value of constant-dollar industry shipments (and hence the energy output ratio) after the oil price shocks. A constant proportional energy/output ratio is adopted for the forecast.

specific forecast prevents the desired further disaggregation of upstream chemicals into organic, inorganic, fertilizers, and plastics and synthetics, and it also prevents the disaggregation of the glass, cement, stone, and clay sector into its component parts. Inputting the state-level data required for a base-year benchmark at these additional levels of disaggregation was both prohibitive and unwise. For the above reasons, even though INRAD is based on an aggregation of data that is amenable to state-level modeling, it uses national rather than state-level data.

The INRAD model is intended to incorporate recent trends in energy use and industry growth (from 1981 through 1985). Furthermore, the model is based on the assumption that industry mix accounts for most of the regional variation observed in aggregate industry price responses, and reasonable disaggregation captures most of these regional differences.

3.2.5 Time and Budget Constraints

Because of the time and budget constraints limiting the scope of this project, and because energy use is concentrated in only a few industries, INRAD disregards economic theory that recommends estimating individual model parameters for each of the NEI industries. These parameters are considered to have a negligible impact because of the small amount of energy involved in these industries. However, to maintain the difference in state-specific industrial growth in the state-level forecasts, the common national INRAD equation for the total of all NEI industries is applied to each state's industry-specific growth forecast.

4 Econometric Analysis of INRAD

This section describes the econometric analysis performed on INRAD. Two personal-computer (PC) software packages were used: Regression Analysis and Times Series (RATS) was used for initial data exploration, and Lotus 1-2-3 was used for assembly. The analysis was performed using Version 4.1b of the Times Series Processor (TSP) software package on a Suny-Binghamton mainframe computer. Single-equation and two-equation systems were estimated, with cross-equation restrictions imposed in the system. In general, the two-equation systems were statistically justified, based on log-likelihood chi-square tests. The systems were run as iterative Zellner seemingly unrelated regressions.

Although the residuals from the estimated models usually exhibited some serial correlation, this correlation varied across specifications, industries, and equations. Each equation was reestimated with first-order autoregression (AR) corrections. On the basis of log-likelihood chi^2 tests, in some cases the AR correction was significant for only the fossil fuel equation or only the electricity equation. The model estimates presented in Table 4 are based on the significance of this test for the appropriate AR correction. The AR correction was significant for both the fossil fuel and electricity equations for SICs 33FE and 33AL. The AR correction was significant for only the electricity equation for SICs 22, 26U, and 32. AR corrections were not applied to SICs 20 and 28 and NEI since these were not statistically justified.

Plots of residuals and of the analysis of residuals suggested the need for slope and intercept dummies at 1973 and 1974. An exploration of the technological change variables posed questions about a singularity in the matrix, which prevented regression analysis. The data were scaled, and some elasticities were found to be sensitive to the normalization, suggesting that the estimates of the parameters were fragile.

Plots of regression residuals were examined, and some residuals failed the Box Jenkins tests and the normality tests (Jarque-Berce tests). Thus, parameter estimates were further weakened. Dummies for 1973 and 1974 helped, but the elasticities stabilized when the data for 1973 and 1974 were removed. Although this may not be considered an appropriate statistical procedure, the equilibrium factor-demand approach did not appear to represent the disequilibrium in the energy markets of 1973 and 1974. In future research, a disequilibrium model, including 1973 and 1974 data, may be fruitful.

TABLE 4 Estimated Coefficients and t-Values[a]

		a		a_{EF}		a_{iK}		a_{iL}		a_{iU}		γ_{iT}		γ_{iU}		γ_{iDT}	
SIC Code	Dependent Variable	Coeff.	t-ratio	Coeff.	t-ratio	Coeff.	t-ratio	Coeff.	t-ratio	Coeff.	t-ratio	Coeff.	t-ratio	Coeff.	t-ratio	Coeff.	t-ratio
20	F/Q	-0.226	-1.1	0.104	1.8	0.428	0.55	-0.413	-0.8	1.03	1.6	0.0197	1.5	0.0129	0.07	NA[b]	NA
	E/Q	0.0227	0.8	0.104	1.8	0.19	1.1	0.43	2.8	-0.45	-2.6	0.0135	0.9	-0.0345	-2.3	NA	NA
22	F/Q	0.456	1.6	-0.190	-1.3	-0.896	-1.2	0.067	0.14	1.682	2.8	-0.023	-2.0	0.0309	0.2	NA	NA
	E/Q	0.162	2.0	-0.190	-1.3	-0.035	-0.07	0.294	1.0	0.255	0.5	0.0330	2.5	-0.0612	-1.3	NA	NA
26U	F/Q	11.25	5.8	1.204	4.8	-21.82	-3.6	16.20	3.8	-11.96	-2.1	-0.0076	-1.0	-4.630	-2.6	-65.05	-8.4
	E/Q	-0.460	-1.8	1.204	4.8	-2.059	-1.9	0.712	1.0	3.220	2.6	0.0233	2.6	-0.532	-4.1	4.517	2.9
28U	F/Q	0.0057	4.0	-0.85e-4	-6.2	0.0029	0.5	-0.0091	-2.5	0.0178	4.2	-0.0079	-2.4	-0.47e-4	-2.8	NA	NA
	E/Q	0.00095	2.5	-0.85e-4	-0.2	0.0022	0.7	0.00035	0.2	-0.00094	-0.5	0.00560	1.3	-0.28e-4	0.9	NA	NA
32	F/Q	0.240	0.2	0.909	3.7	7.467	1.9	-7.992	-3.1	11.858	3.7	0.00537	0.6	-1.616	-2.2	NA	NA
	E/Q	-0.049	-0.5	0.909	3.7	-0.0076	-0.1	1.288	2.3	-0.996	-2.0	0.00891	0.9	-0.145	-3.9	NA	NA
33FE	F/Q	4.677	0.9	1.498	6.9	0.923e-3	0.3e-3	14.71	2.0	-18.68	-1.9	-0.0023	-0.1	0.722	0.8	NA	NA
	E/Q	-0.433	-3.9	1.498	6.9	-0.612	-0.8	2.811	5.2	-2.953	-3.5	NA	NA	-0.0756	-1.9	0.9936	4.5
33AL	F/Q	-11.68	-1.7	11.365	2.7	37.936	1.8	-36.27	-1.9	50.09	2.2	-0.120	-4.9	-1.968	-0.4	NA	NA
	E/Q	4.709	0.9	11.365	2.7	40.989	1.0	22.673	0.8	-55.4	-1.5	NA	NA	4.850	0.6	NA	NA
NEI	F/Q	0.53e-3	4.7	0.38e-4	1.0	0.54e-2	1.3	0.36e-3	1.3	-0.77e-3	-2.9	-0.0464	-3.1	NA	NA	NA	NA
	E/Q	0.29e-4	0.2	0.38e-4	1.0	0.31e-3	1.0	0.52e-4	0.3	0.84e-4	0.5	-0.00268	-0.3	NA	NA	NA	NA

[a] E = electricity, Q = output, F = fossil fuel, i = input, K= capital services, L = labor, U = capacity utilization rate, T = level of technology, DT = industry-specific technology.

[b] NA = not applicable.

5 Supplemental Driver Forecasts for INRAD

To implement INRAD in the ECIMs, forecasts of technology penetration and industry output are required in addition to the data on energy and production factor prices described previously. This section describes the technology penetration forecast and the supplemental analysis performed to relate the available Federal Reserve Board (FRB) production index (Federal Reserve Bulletin various dates) to the data on shipments from the Bureau of Labor Statistics (BLS various dates) that were used to create the model estimates.

5.1 Technology Penetration Forecasts

The penetration of technology is usually described by an adoption and diffusion model. However, because TMP and EAF technologies cause changes in energy use, they may be affected by energy prices. Both these technologies create major shifts in the pattern of fossil fuel versus electricity use. The logit model is usually applied to model this market adoption. Logit function analysis of the national production shares of TMP and EAF is used to determine how prices affect the penetration of major process changes. The analysis presented here is based on a simple logit function analysis of national data on EAF and TMP market shares.

The logit equation is based on the following logistics equation:

$$S = A[e^{rt}/(1 - e^{rt})] \tag{5.1}$$

where:

S = market share,

A = maximum market share, and

r = penetration parameter being estimated.

This equation may be transformed into a linear equation:

$$\ln[s/(1 - s)] = c + rt \tag{5.2}$$

where:

s = S/A and

c = parameter being estimated.

It is also possible to add other explanatory variables to the logit model. This is accomplished by appending additional linear terms to Eq. 5.2.

The logit analysis of national market share requires estimates of the technology's maximum penetration. Engineering estimates of this maximum are imposed, since distinct engineering limits need to be represented. Production shares of 11% for TMP and of 55% for EAF were used for current estimates and forecasts. For future forecasts, recycling and other materials policies might have significant effects on these limits.

The parameters of the logit model are summarized in Table 5. The price term is the log of the ratio of electricity prices to fossil fuel prices. In both the EAF and TMP equations, the coefficient has the correct sign but is only marginally significant. The inclusion of prices in the logit equations did not significantly improve the statistical fit, thus suggesting that energy prices do not have a large impact on the decision to adopt these process changes. The size of the coefficients indicates that TMP is being adopted very rapidly and EAF is being adopted more slowly. Because the price coefficients are not significant, the forecast is based on trend estimates for each technology (see Fig. 2).

5.2 DRI Bridge Equations

The forecast for industry output is taken from the DRI/ECIMS data file on regional activity for all two-digit SIC industries. Regional forecasts for industries at levels more specific than the two-digit level are not available from DRI; however, INRAD requires forecasts for four sectors below the two-digit level: upstream paper (26U), upstream chemicals (28U), ferrous metals (33FE), and aluminum (33AL). Analysis suggests that for three of these sectors (all except upstream chemicals), a forecast proportional to the corresponding two-digit sector is reasonable. For the chemicals industry, however, the total sector (SIC 28) is growing much more rapidly than the upstream sector (SIC 28U). Therefore, a separate equation is used to relate time and DRI forecasts of fertilizer demand, rubber and plastics demand, petroleum demand, and feedstock costs to an index of shipments in SIC 28U. This "bridge equation" is used in INRAD for the upstream chemicals sector. The results of the analysis are presented in Table 6.

A second issue is the relationship between the output measure upon which INRAD is based (BLS shipments) and the forecast concept (FRB production index). If the value of materials is increasing, shipments should grow faster than value added. If this is not the case, the FRB index may grow more slowly. Also, the product mix and the data proxies used by the FRB to construct its (timely) index may not be representative of actual output.

To estimate these differences, a simple log-linear regression was run for each industrial sector, using the following formula:

$$\mathrm{BLS} = c \times \mathrm{FRB}^{\alpha} \times e^{rt} \times e^{\beta CU} \tag{5.3}$$

TABLE 5 Results of National Technology Market Share Analysis

	Estimates of Logit Function Coefficients and t-Ratios			
	Trend Analysis		Price Analysis	
Technology,[a] Time Period, and Term	Coefficient	t-ratio	Coefficient	t-ratio
TMP (1977-1985)				
Constant term	-8.955	-13.16	-6.925	-4.17
Trend term	0.306	10.89	0.320	11.2
Price term			-1.653	-1.32
R-bar^2	0.936		0.942	
EAF (1958-1985)				
Constant term	-2.055	-50.62	-1.585	-4.50
Trend term	0.087	35.703	0.080	13.6
Price term			-0.2067	-1.34
R-bar^2	0.979		0.979	

[a] TMP = thermomechanical pulping; EAF = electric arc furnace.

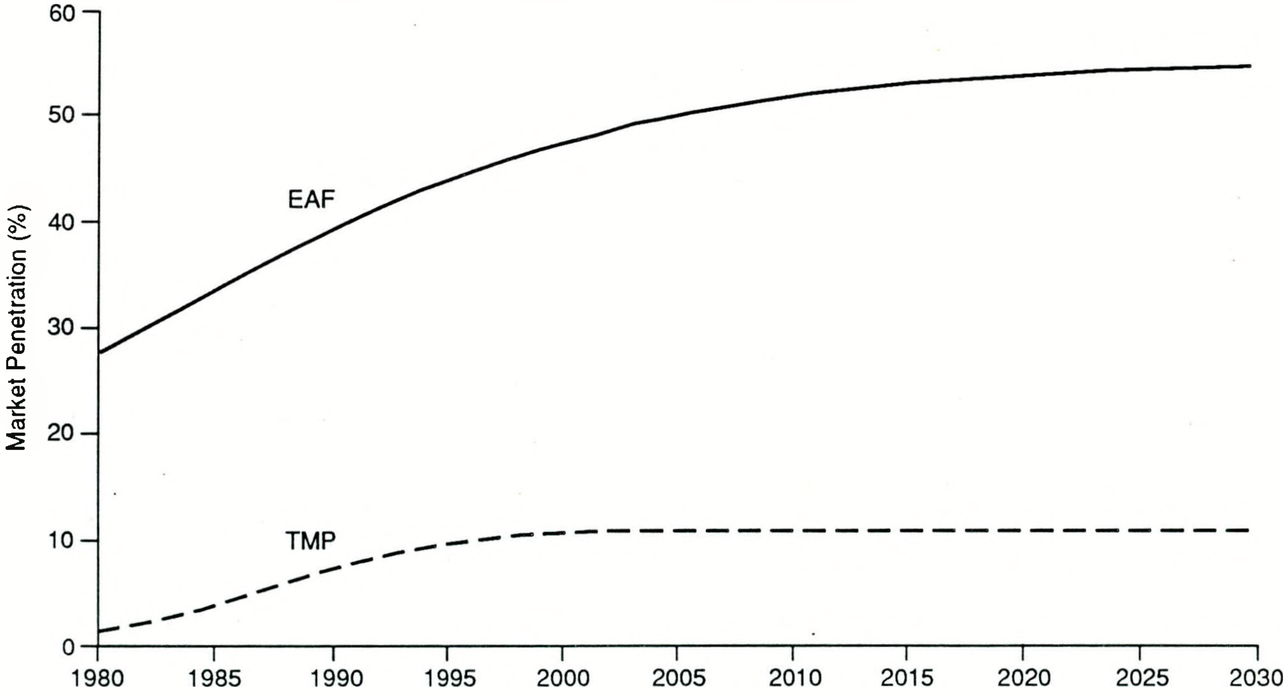

FIGURE 2 Projection of Market Penetration for Electric Arc Furnaces and Thermomechanical Pulping

TABLE 6 Bridge Equation Estimates for Upstream Chemicals (SIC 28U)[a]

Estimated Value	Variable[b]					
	TIME	Constant	GOAG	WPIND@05	JQIND30	JQIND29
Coefficient	0.358	0.482	-0.482e-2	0.293	0.581	0.0193
t-ratio	2.0	2.9	-3.0	2.9	5.2	-3.9

[a] $R^2 = 0.98$, DW = 2.1, and time period is 1969-1985.

[b] Definitions of the variables are as follows:

TIME = time trend
GOAG = generated output from the agricultural sector
WPIND@05 = wholesale price index of industrial commodities except energy
JQIND30 = FRB index for SIC 30 (rubber and plastics)
JQIND29 = FRB index for SIC 29 (petroleum and allied products)

where:

BLS = output measure from BLS (shipments),

FRB = output measure from FRB (production index), and

CU = capacity utilization rate.

This formulation allows for both proportional and constant exponential differences to occur in these measurement trends. The capacity utilization rate term helps to control for the large fluctuations in industry output that occurred in energy-intensive industries during the 1970s. The results of the analysis are presented in Table 7. There is a remarkable tendency for α to be less than one (in 14 of 17 sectors) and r to be negative (in 7 of 9 sectors). Both these tendencies show that BLS output measures (which were used to estimate parameters) are growing less rapidly than FRB output measures.

TABLE 7 Bridge Equation Estimates for the Industrial Sector[a]

SIC Code[b]	α	r	ß	R^2
20	0.992191	-0.00098		0.71
	(0.27)	(0.001)		
22	0.963446	-0.00117	-0.26899	0.97
	(0.06)	(0.0009)	(0.09)	
23	0.516731	-0.00058	-0.26965	0.71
	(0.15)	(0.002)	(0.23)	
24	0.885085	-0.00484	-0.37607	0.95
	(0.09)	(0.002)	(0.17)	
25	1.071664	-0.0012	-0.22109	0.99
	(0.6)	(0.001)	(0.11)	
27	0.939525			0.91
	(0.11)			
30	0.952623			0.94
	(0.09)			
31	0.815248			0.79
	(0.17)			
32	0.890047			0.97
	(0.06)			
33FE	1.017021	-0.00286		0.94
	(0.09)	(0.003)		
33AL	0.959453	-0.01273		
	(0.36)	(0.007)		
34	0.821863			0.96
	(0.06)			
35	0.937953			0.99
	(0.04)			
36	0.977425	0.001758		0.98
	(0.05)	(0.0009)		
37	1.195435			0.97
	(0.08)			
38	0.990057			0.92
	(0.11)			
39	0.945211	0.00112		0.97
	(0.07)	(0.001)		

[a] Standard error in parentheses.

[b] Unsatisfactory estimates were obtained for SICs 21, 26, and 29. A special equation was developed for SIC 28U (see Table 6).

6 State-Level Forecasting in INRAD

The INRAD model is implemented in the ECIMS as a set of Fortran codes that run in both an integrated and a standalone mode. The national-level equations are implemented in the ECIMS at the state level by assuming common price elasticities in each industry across all states. To preserve the elasticities for state-level energy prices, it is necessary to compute a multiplicative benchmark of the national-level equation to the state-level energy intensity. State-level, industry-specific energy prices are input into the INRAD energy intensity equations used to compute a state-level energy intensity. Because the goal is to forecast energy use, the benchmarking is done by applying both the forecasted growth rate in industry output for a state and the growth rate for the corresponding predicted energy intensity to base-year, state-level energy use. The use of growth rates is equivalent to computing a multiplicative benchmark for each state. All the benchmarks are for 1980.

INRAD obtains the forecast of state-level, industry-specific prices from other models in the ECIMS. When running in the annual recursive mode, INRAD takes the state growth rate in average industrial electricity prices from AUSM and applies this rate to the industry-specific, base-year electric rates. This procedure is done to account for industry-specific and state-specific base-year differentials and forecast trends in prices. The industry-specific and state-specific fossil-fuel price index is constructed by taking 1980 industry-specific weights for residual oil, distillate oil, natural gas, and coal consumption (in Btu) and weighing the corresponding state-level price forecasts from the ECIMS price module.

A final adjustment is applied to the growth in industry output. In the case of SIC 28 (chemicals), the bridge equation from Table 4 is used directly. For all other industries, the results from the regression model that was presented in Tables 5 and 6 are applied to the DRI forecast for the FRB indexes. Since the model is implemented using growth rates rather than levels, the state-specific industrial growth rate is modified as follows:

$$\frac{Inew_{s,t,n}}{Inew_{s,t-1,n}} = \left(\frac{Ifrb_{s,t,n}}{Ifrb_{s,t-1,n}} \right)^{\alpha_n} - r_n \tag{6.1}$$

where:

Inew = adjusted index,

s = state,

t = time,

n = industry,

Ifrb = FRB index, and

α, r = industry-specific parameters for industry n.

To drive the industrial energy-related emissions models ICE and PROMPT, slightly more disaggregated data than state-level fuel use data are required for two-digit SICs. The ICE model requires state-level boiler fuel-use data for seven industry groups (SICs 20, 22, 26, 28, 29, 33, and all "other"). The need for industry detail in the ICE driver is one of the reasons for using INRAD to forecast disaggregated industrial-energy demand. The PROMPT model requires federal-region-level process fuel-use data use for various industry-specific processes that generate SO_2 and NO_x emissions.

The ICE boiler fuel-use forecast is obtained by benchmarking the INRAD fossil-fuel forecast to the ICE model's base year. This benchmarking is done by using growth rates in much the same way as described above. The state-level, industry-specific growth rate of fossil fuel use from INRAD is applied to the 1985 base-year data in ICE. This procedure is consistent with the assumption that the share of boiler fuel use to total fuel use is constant. The implied boiler fuel ratio will vary by industry and state but not over time.

The driver for PROMPT is based on process fuel-use shares forecasted by the ISTUM-II model's process engineering model of industrial energy use (DOE 1979). The total process fuel use for the United States is computed as a residual from INRAD and ICE; that is, the forecast of boiler fuel use is subtracted from the forecast of total fossil fuel use for each industry. This gives a process fuel use total. This total is used to calibrate the forecast from the ISTUM-II model and obtain levels of process fuel use for each PROMPT emission category.

The INRAD code implemented on the SUN workstation network was run in a standalone mode using historical prices and activity levels. Data from the U.S. Department of Energy manufacturing energy consumption survey (MECS) were compared with the 1985 INRAD estimates. National-level results on total fossil fuel and electricity demand were compared for each two-digit SIC code from 20 through 39. The INRAD and MECS results show good agreement at the aggregate level. However, electricity demand is 5% higher in INRAD than in MECS, and fossil fuel demand is 6% higher in INRAD. This backcasting bias is borne out in the industry-specific results too. One possible explanation relates to capacity utilization. INRAD was designed for long-run forecasting (i.e., forecasting that does not account for business-cycle fluctuations). At the national level, the statistical basis for the parameters used in INRAD does include capacity utilization. At the state level in the ECIMS code, however, this capacity utilization parameter is not implemented because of a lack of state-level data on business cycles. Because the estimated relationship between capacity utilization and energy intensity is usually negative, the fact that this relationship is not modeled could contribute to INRAD's tendency to overestimate 1985 industrial energy use.

The industry-level results show a few significant outliers (values of more than one) to the INRAD tendency to overestimate 1985 energy use. Figure 3 shows the ratio of 1985 MECS data to INRAD estimates. For most industries, the value is less than 100%, indicating

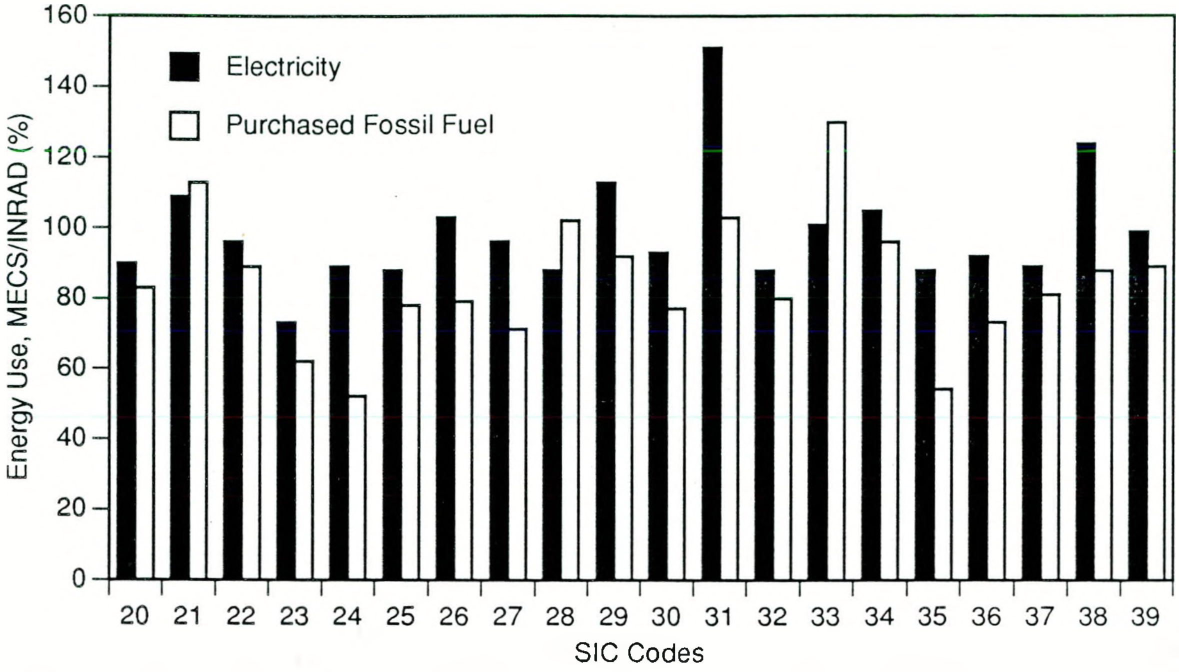

FIGURE 3 Ratio of 1985 MECS Energy Use to That of the INRAD Simulation

overestimates by INRAD. Some of these values are as low as 60% or less. However, these industries are minor in terms of energy use; thus, less emphasis has been placed on modeling their energy use. (Their long-run growth potential in the economy suggests that in the future, additional effort should be made to estimate the energy use of these industries.) The most significant industry with respect to electricity demand is SIC 28 (chemicals). The difference between MECS and INRAD data in SIC 28 constitutes 2.5% of electricity demand in the total manufacturing sector (see Fig. 4). Because the chemicals and allied products sector is so diverse, it may require additional disaggregation for its energy demand to be modeled accurately.

The major deviation between the MECS and INRAD 1985 fossil fuel estimates occurs in the primary metals industry (SIC 33). In this case, INRAD underestimates fossil fuel use by 30% (see Fig. 4). This underestimate accounts for more than 5% of fossil fuel use in manufacturing (see Fig. 4). Significant underestimates of fossil fuel use in SICs 20, 26, and 32 work to offset this difference in the total manufacturing statistics. To improve INRAD's overall accuracy, additional work on modeling this sector would be appropriate.

Energy prices in the period from 1980 to 1985 were unusual when compared with those of the 1970s. In the early 1980s, a sharp drop in oil prices and corresponding changes in the carriage market for natural gas significantly lowered energy prices. INRAD's tendency to overestimate energy use may be due to the irreversible nature of conservation improvements and the model's symmetric treatment of how energy prices affect energy use. In other words, the model assumes that when energy prices fall, the industrial sector will use more energy. However, this pattern may not always occur, especially when one accounts for the more efficient

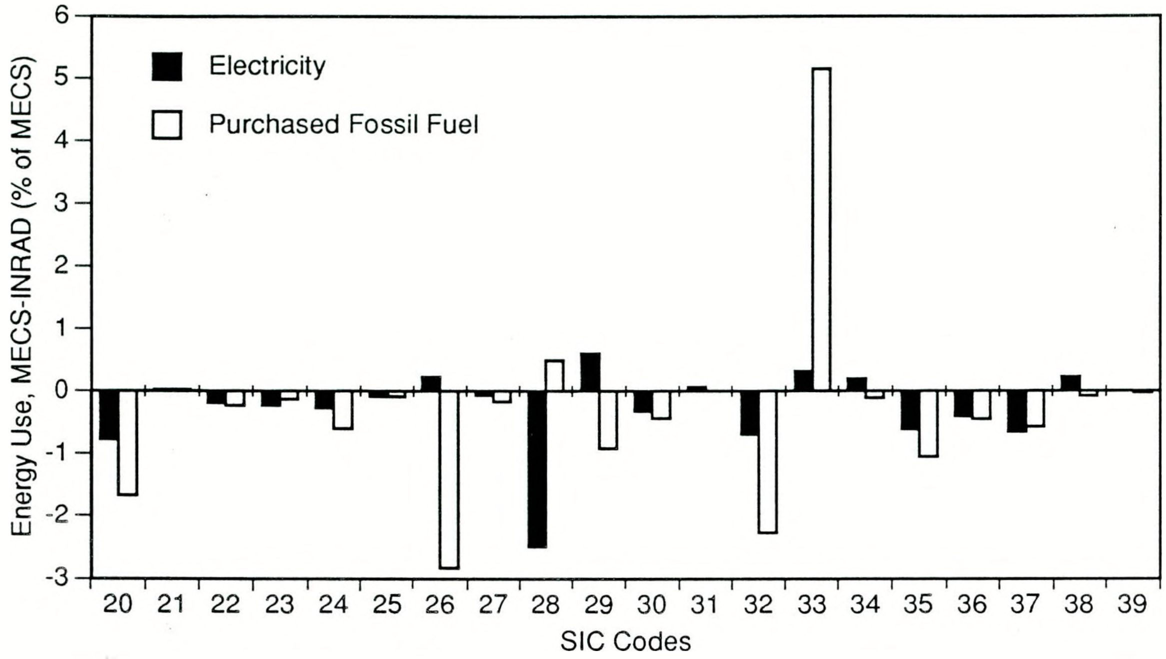

FIGURE 4 Difference between MECS and INRAD as a Percent of Total Industrial Energy Use in MECS

capital stock that was installed by the industrial sector during an era of rising prices. This effect, combined with the capacity utilization phenomenon, both contribute to the overestimation of energy use by INRAD. Although the total overestimate, 5% for electricity and 6% for fossil fuel, is not large, it should be as small as possible, given the important influence of the energy forecast on the emissions forecast.

Another important dimension of INRAD's simulation of the historical period is its relationship to the 1985 base-year energy data in ICE and PROMPT. The inputs to ICE are based on the ratio of state-level, industry-specific fuel use in the ICE model's base year to the total fuel use estimated by INRAD. This implied boiler ratio is held constant for the forecast. If the boiler ratio is frequently larger than one, there is substantial disagreement between ICE and INRAD. The inputs to PROMPT are based on the difference between ICE and INRAD; i.e., the difference between boiler fuel use and total fuel use is assumed to be accounted for by purchased fossil-fuel use in industrial processes. Because PROMPT is driven by a forecast at the federal-region level, the connection between INRAD and PROMPT is represented as a national scaling factor. These boiler ratios and the PROMPT model's scale factor can be reviewed to assess the degree of correspondence among INRAD, ICE, and PROMPT in the reference year 1985.

Figure 5 is a box plot showing how the implied industrial boiler ratios vary by state. Each vertical line represents a state-level value. The box plot gives the quartile ranges and median values of the boiler ratios. These plots are truncated at unity (one). The driver interface does not allow boiler ratios of greater than one. However, several outliers (values above one)

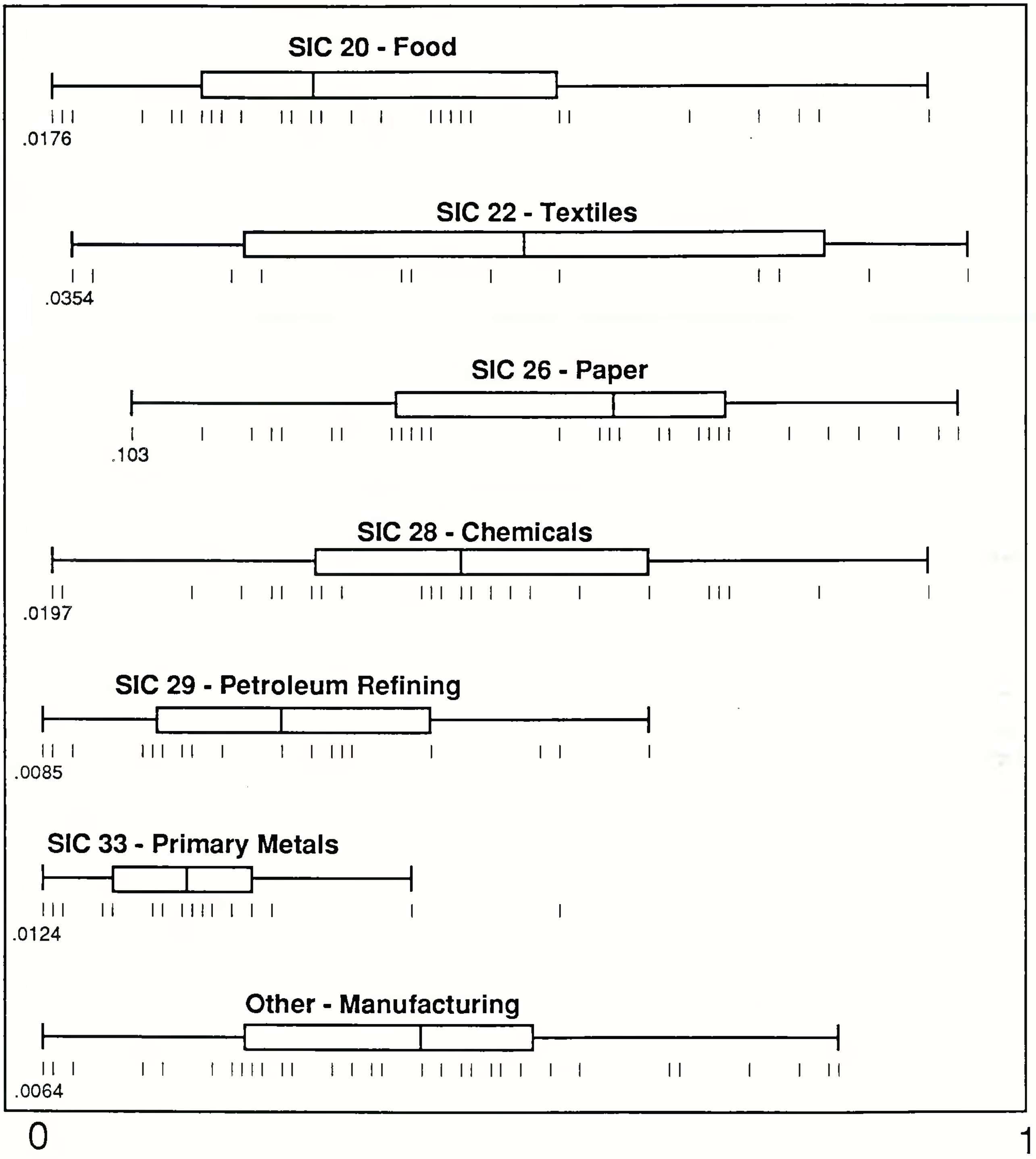

FIGURE 5 Distribution of State-Level Boiler Fuel-Use Ratios Implied by the 1985 ICE Model and INRAD Backcast without Outliers

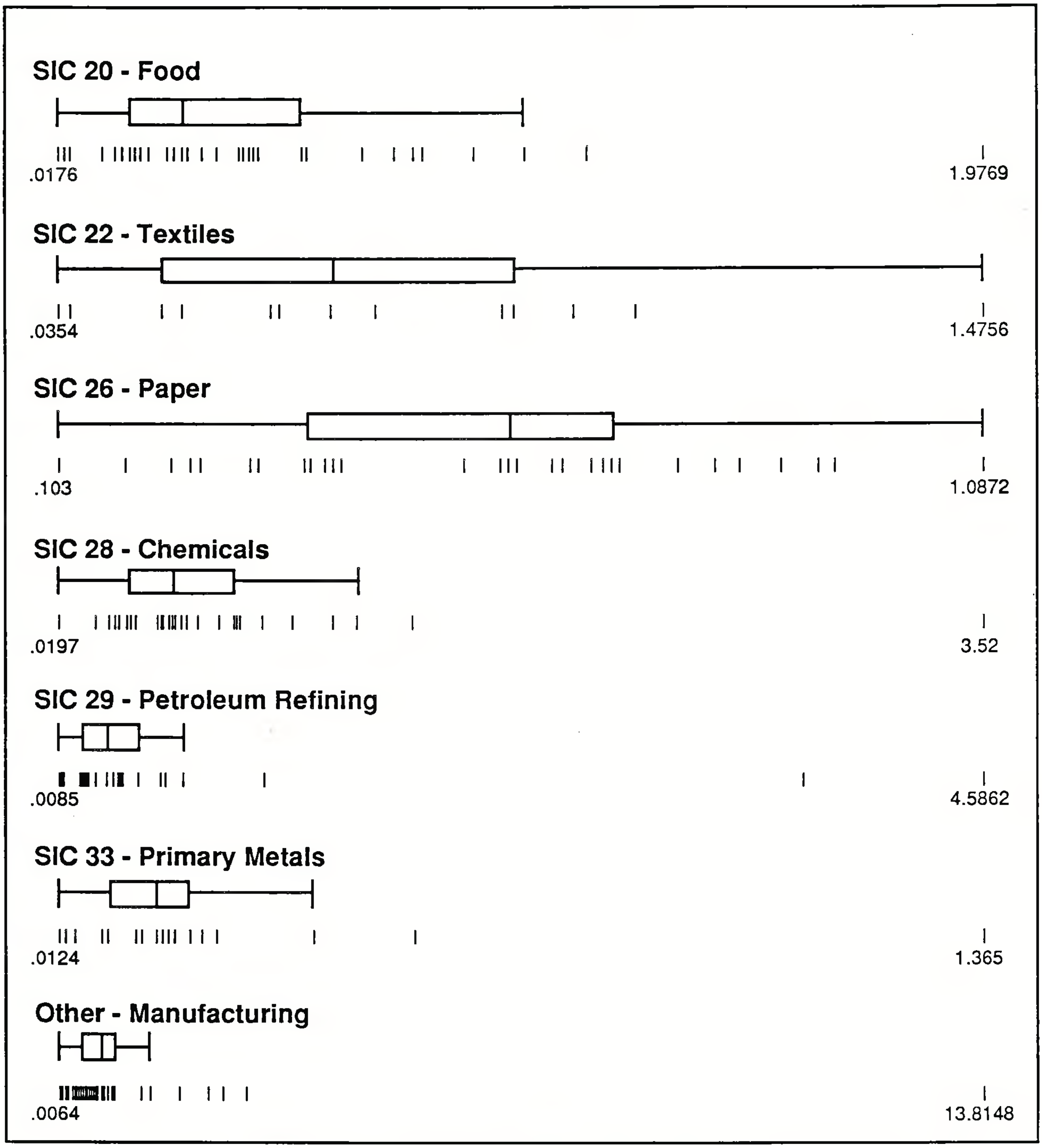

FIGURE 6 Distribution of State-Level Boiler Fuel-Use Ratios Implied by the 1985 ICE Model and INRAD Backcast Including Outliers

do occur in the data. Figure 6 shows plots with the outliers included. These outliers are 3, 1, 1, 3, 3, 1, and 8 for SICs 20, 22, 26, 28, 29, 33 and "other," respectively. More than half of these outliers are very close to unity. Because the remainder are for states with very little industrial activity or energy use, they do not contribute much to the total forecast. For example, the state with a 13.8 boiler ratio in "other" is Wyoming. In total, these outliers account for less than 2% of total boiler fuel use in the ICE model.

The general distribution of the boiler ratios across SIC codes conforms with knowledge about the energy-use patterns in these industries. The petroleum refining (SIC 29) and primary metals (SIC 33) industries have low boiler fuel-use shares and high process fuel-use shares. The paper (SIC 26) and chemicals (SIC 28) industries are quite similar, having larger boiler fuel demands. The boiler ratio in the food industry (SIC 20) is lower but varies significantly. There is significant variation in textiles (SIC 22) and the "other" industries. In summary, there seems to be surprisingly good agreement between ICE and the INRAD simulation, despite the presence of several outliers.

After accounting for the boiler fuel demand, the ECIMS interface between ICE and PROMPT computes the ratio of total nonboiler fuel use (i.e., INRAD minus ICE) and scales the base forecast of purchased fuel in PROMPT. This scaling factor is another measure of the correspondence between the 1985 INRAD estimates and the PROMPT and ICE energy data bases. This scaling factor is 0.89. In other words, PROMPT estimates 11% more purchased fossil fuel use than does the estimate obtained by subtracting ICE from INRAD. However, the agreement between the estimates is reasonably close, given the paucity of data collected on boiler versus process fuel use.

7 Interpretation of INRAD Estimates

In this section, the estimates of the INRAD model are interpreted. These estimates include the price terms and the technology coefficients. The most common way to interpret the price terms is in the form of an elasticity. The data on the technology coefficient, capacity utilization, and technical change are compared with similar engineering information.

7.1 Major Industrial Energy Demand Elasticities

Estimates of the price responsiveness of each industry are derived from the INRAD model's parameter estimates and each year's price levels. The parameter estimates and historical prices are combined to compute the demand (own-price) and cross-price elasticities. A price elasticity is defined as the percentage change in (energy) demand as a result of a 1% change in a price. The own-price elasticity is the percentage change in demand for one type of energy, given a change in its own price. Own-price elasticities are negative or zero, indicating a reduction in demand when prices increase. The cross-price elasticity is the percentage change in demand for one type of energy, given a change in the price of another type. When the cross-price elasticity is positive, two energy types can substitute for each other. In other words, when the price of one energy type goes up, more of the other type is used.*

The elasticities obtained by the model estimates are summarized in Table 8. The ranges in fossil fuel demand elasticities indicate a decrease in fossil fuel demand of 10-60% for a 100% increase in fossil fuel prices. An even wider range of response in electricity demand, a 10-90% decrease, occurs for a similar increase in electricity rates. Many industries exhibit substitution between fossil fuels and electricity (i.e., have positive cross-price effects), so that a 100% increase in electricity rates would increase fossil fuel use 20-40%. (Only the food industry exhibited historically complementary trends in the demand for different energy types.) This substitution has important implications for modeling SO_2 emissions and points out the importance of modeling fossil fuel and electricity demand jointly, since emissions could be shifted from the electric utility sector to the relatively less regulated industrial sector.

The elasticities shown in Table 8 are based directly on the estimates presented above. The elasticities are computed from the sample data for each year, and the means and two standard deviations of these estimates are reported. When one is making forecasts for scenarios in which real energy prices are increasing or policy analyses of the impacts of additional price shocks, behavior of the model *as it is implemented* (i.e., at the state level) is of primary concern. Table 9 shows the elasticities that were implied by a simple simulation holding all prices constant, then

---

*The discussion here is simplified by avoiding the debate over appropriate elasticities of substitution. Blackorby and Russell (1989) point out that the sign of the cross-price elasticity determines the direction of substitution in the Allen elasticity. Future analysis will include the Morishima elasticity as well.

TABLE 8 Fossil Fuel and Electricity Demand Elasticities and Cross-Price Elasticities Based on INRAD Estimates

Industry Description	SIC Code	Demand Elasticity[a]				Cross-Price Elasticity
		Fossil Fuel		Electricity		
Food	20	-0.5	(0.04)	-0.4	(0.1)	0.2
Textiles	22	-0.3	(0.06)	-0.2	(0.08)	-0.3
Upstream paper	26U	-0.1	(0.06)	-0.9	(0.3)	0.4
Upstream chemicals	28U	-0.4[b]		≈0		≈0
Glass, cement, stone, and clay	32	-0.6	(0.6)	-0.7	(0.8)	0.2
Ferrous metals	33FE	-0.2	(0.04)	-0.8	(0.3)	0.3
Aluminum	33AL	-2.7	(2.2)	-0.1	(0.08)	[c]

[a] Estimate of two standard deviations is given in parentheses.

[b] Standard error not available.

[c] Not provided because fossil-fuel use in this sector is negligible.

TABLE 9 Own-Price Elasticities Based on State-Level INRAD Simulations

Industry Description	SIC Code	Own-Price Elasticity	
		Electricity	Fossil Fuel
Food	20	-0.24	-0.30
Textiles	22	-0.06	-0.15
Upstream paper	26U	-0.30	-0.07
Upstream chemicals	28U	-0.03	-0.10
Glass, cement, stone, and clay	32	-0.31	-0.37
Ferrous metals	33FE	-0.28	-0.09
Aluminum	33AL	-0.08	-2.27
Non-energy-intensive (NEI)[a]		-0.20	-0.01

[a] Initial work has been done on one non-energy-intensive industry, SIC 35. The simulation shows quite different results for the elasticities: -0.33 for electricity and -0.46 for fossil fuels. Further analysis of these sectors may be called for.

doubling fossil-fuel prices and increasing electricity prices by one-third. These apparently different price changes are of approximately the same magnitude as those given in terms of absolute dollars per Btu. The fact that these elasticities are substantially lower than those obtained from the sample period illustrates that some type of diminishing marginal effect of prices on energy intensity is imposed by this particular model.

7.2 Interpretation of Engineering Parameters

The modeling analysis uses a mixture of traditional economic modeling and engineering data to obtain improved estimates of energy intensity. The previous section focused on traditional economic measures; this section focuses on the engineering side of the statistical analysis -- specifically on the model's parameter estimates (γ), which are associated with the technology-specific variables (DT).

Table 10 shows the three electrotechnology coefficients that were estimated: (A) the effect of a 1% shift to TMP on the purchased-electricity intensity of the pulp and papermaking industry (SICs 261, 262, 263, and 266), (B) the effect of same the shift on fossil-fuel intensity, and (C) the effect of a 1% shift to EAF on the purchased-electricity intensity of the iron- and steel-making industry (SICs 331, 332, and 339). The estimated coefficients are in agreement with engineering estimates.

The estimated coefficients indicate that low capacity utilization during recessions leads to an increase in energy intensities. This observation agrees with detailed information from pulp and paper mills and petroleum refineries. This effect appears to be the result of operating underutilized equipment rather than shutting down less energy-efficient production facilities. This latter action may occur only during severe recession.

Specific results for capacity utilization coefficients are shown in Table 11. The ratio of the estimated capacity utilization coefficient to the dependent variable, energy intensity (X/Q) for 1977, is reported. The results show that for the sectors modeled, a 10% decline in capacity utilization results in a 1-3% increase in electricity intensity. There is a similar, but statistically insignificant effect, for fossil fuel.

TABLE 10 Comparison of Coefficients Based on INRAD Estimates with Those Based on Engineering Analysis

Coefficient	Electrotechnology Being Shifted to[a]	Affected Energy Intensity	Estimated Coefficient[b]	Engineering Coefficient
A	TMP	Electricity	4.5	3.1[c]
B	TMP	Fossil fuel	-65.0	Between 0 and -200
C	EAF	Electricity	1.0	0.75[d]

[a] Represents a 1% shift to thermomechanical pulping (TMP) or electric arc furnace (EAF) technology.

[b] The intensity coefficients being modeled are in units of 10^{12} Btu/$100 million (1972 dollars) of output.

[c] Based on 2000 kWh of energy used per ton of pulp produced by TMP.

[d] Based on 700 kWh of energy used per ton of steel-mill product produced by EAF.

TABLE 11 Estimated Capacity Utilization Coefficients[a]

Industry Description	SIC Code	Fossil Fuel		Purchased Electricity	
		Coefficient	t-ratio	Coefficient	t-ratio
Food	20	NS[b]	-	-0.3	-2.4
Textiles	22	NS	-	NS	-
Upstream paper	26U	-0.6	-2.7	-0.3	-4.1
Glass, cement, stone, and clay	32	-0.3	-2.2	-0.3	-4.0
Ferrous metals	33FE	NS	-	-0.1	-2.0
Aluminum	33AL	NS	-	NS	-

[a] Ratio of the estimated of capacity utilization coefficient (expressed as a fraction) to the corresponding energy intensity for 1977.

[b] NS = not statistically significant.

8 ICE and PROMPT Model Runs for NAPAP Scenarios

Within the NAPAP model set, INRAD provides driver inputs to the ICE and PROMPT emission models. Specifically, INRAD provides state-level and industry-level data on boiler fuel use to ICE and (scaled) regional-level and industry-level data on process fuel use to PROMPT. The input data vary, depending on the sensitivity scenario being modeled in the ECIMS. The scenarios reflect different conditions in areas such as economic growth, energy prices, or explicit assumptions about conservation.

The ICE model developed for NAPAP is described in Hogan (1988a,b). INRAD provides data on total boiler fuel use as input to the ICE model, which chooses the fuel mix and forecasts the resulting emissions. Figures 7-10 show the boiler fossil-fuel demand forecasts from ICE, and Figs. 11-14 show the corresponding emission forecasts. The forecasts are provided for NAPAP's reference-case scenario (SC0) and the following three sensitivity scenarios:

SC1: Lower Economic Growth,

SC7: Higher Conservation, and

SC8: Lower Oil and Gas Price.

Detailed computer printouts of ICE model output on emissions, costs, and fossil fuel demand for the NAPAP reference-case scenario only are provided in App. A. National (total), state-level, and federal-region-level forecasts of emissions of SO_2, allowable SO_2, NO_x, sulfates, and particulate matter for 1985, 1990, 1995, 2000, 2010, 2020, and 2030 appear first. Then estimates of annualized costs for these same areas and years are provided. Next, state-level, regional, and national fossil-fuel demand forecasts (in Btu) are included, by year, first for all boilers and then for boilers built since the previous year. Finally, estimates of national fossil fuel demand (by number of boilers) are presented, by year, for boilers built since the previous year. Data are shown for boilers with coal experience, boilers without coal experience, and new boilers, with each category classified by boiler size.

The PROMPT model is based on data from the ISTUM-II modeling system. The PROMPT model is described in EEA (1989). PROMPT was originally a PC-based model that was transferred to the SUN workstation network so it could be run in an integrated mode. PROMPT uses scaled inputs based on the INRAD forecasts.

Detailed computer printouts of PROMPT model outputs for the NAPAP reference-case scenario are provided in App. B. First, two state-level and national (total) forecasts of SO_2 emissions for 1985, 1990, 1995, 2000, 2010, 2020, and 2030 are provided for the industrial process sector. One includes data on emissions from smelters and sulfur processing; the other one excludes these data. Then two corresponding forecasts of NO_x emissions are presented. The first includes data on emissions from pipelines; the second does not.

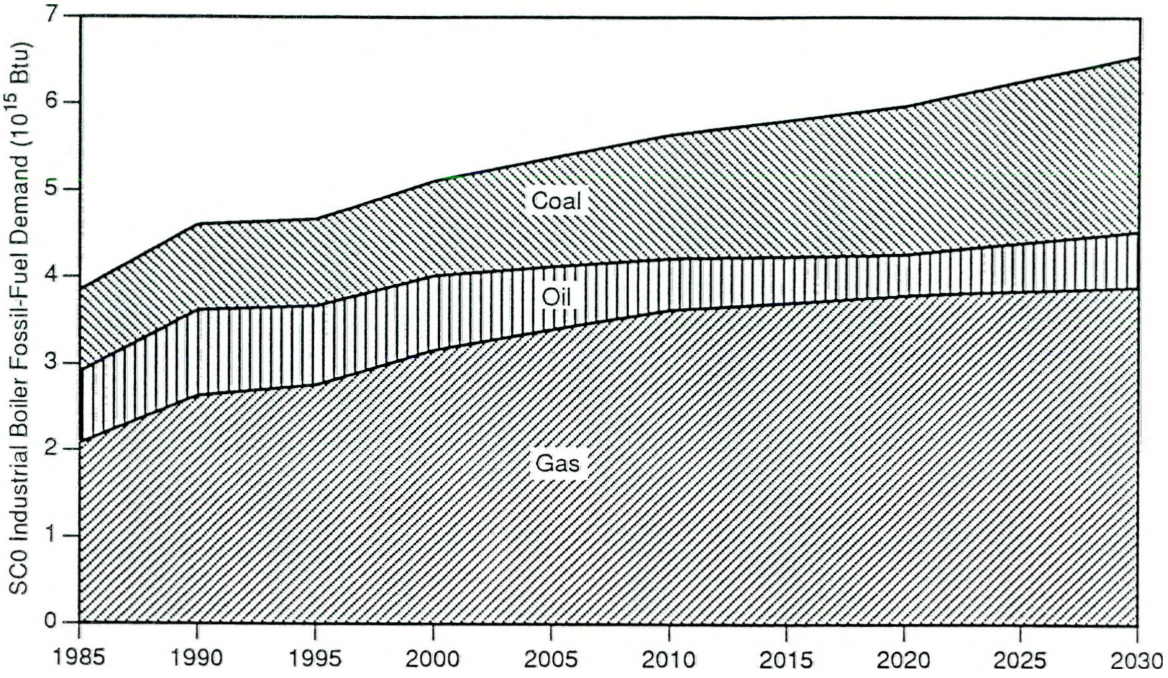

FIGURE 7 ICE Estimates of Boiler Fossil Fuel Demand in SC0

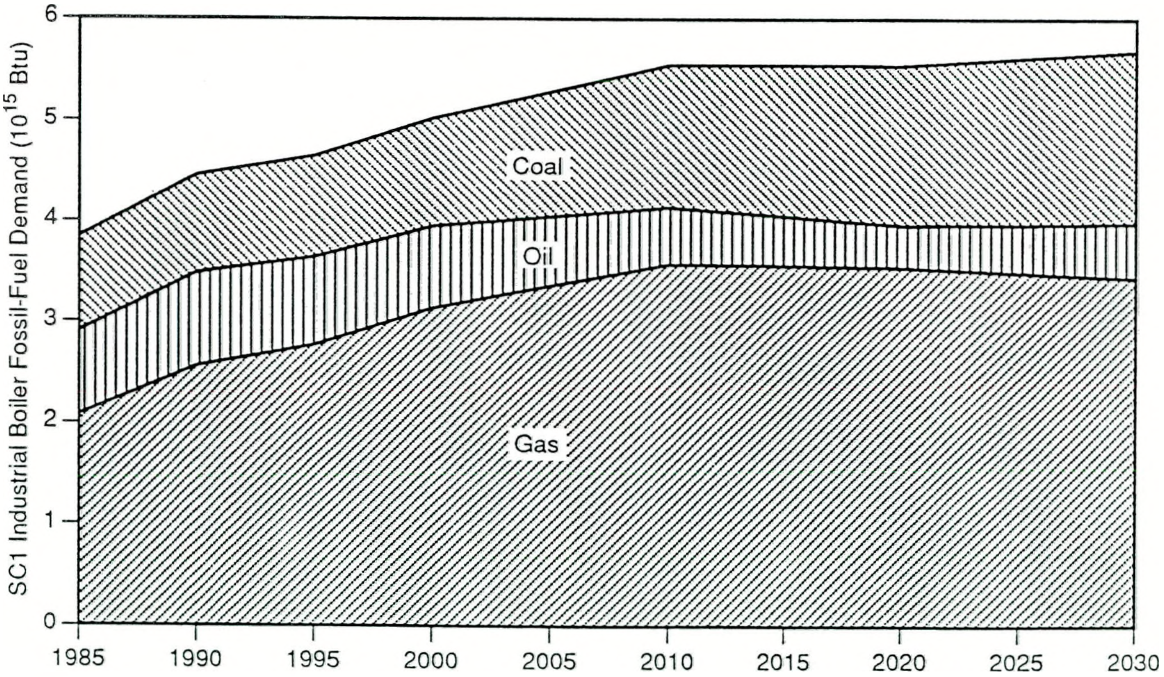

FIGURE 8 ICE Estimates of Boiler Fossil Fuel Demand in SC1

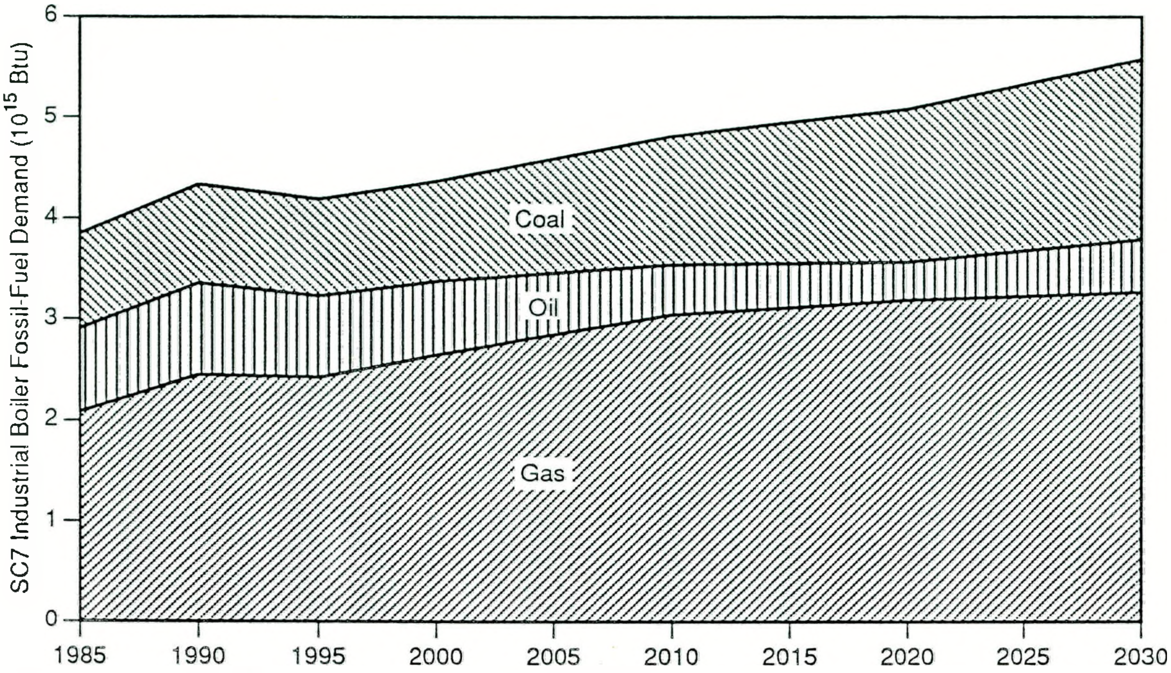

FIGURE 9 ICE Estimates of Boiler Fossil Fuel Demand in SC7

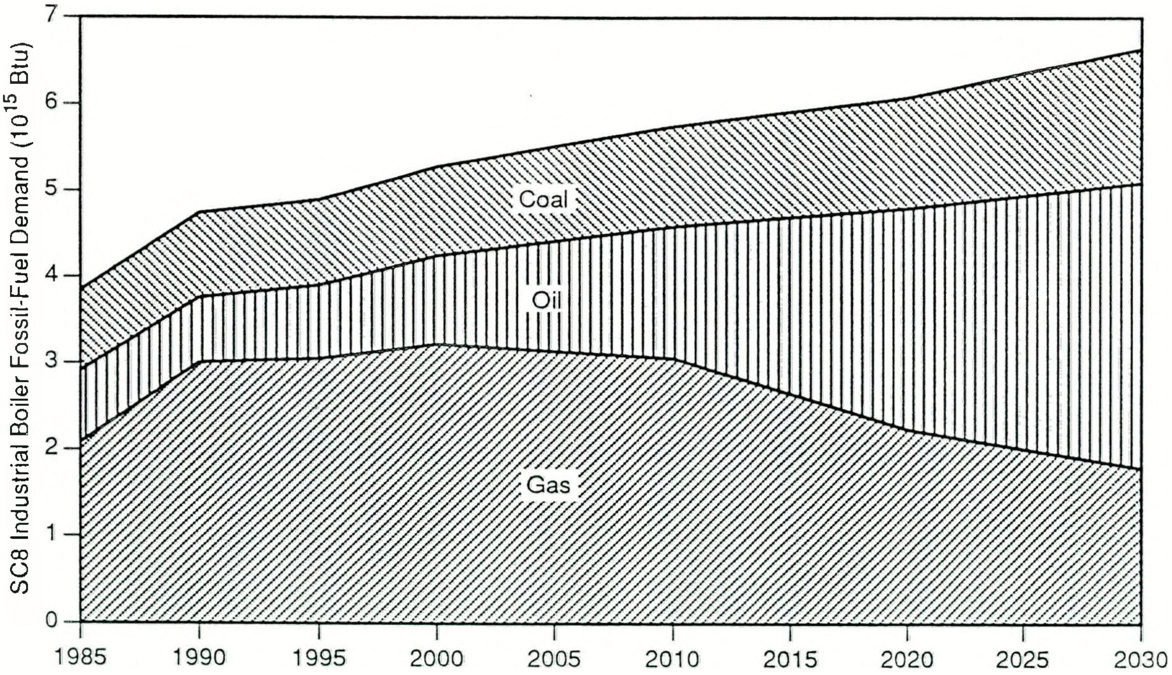

FIGURE 10 ICE Estimates of Boiler Fossil Fuel Demand in SC8

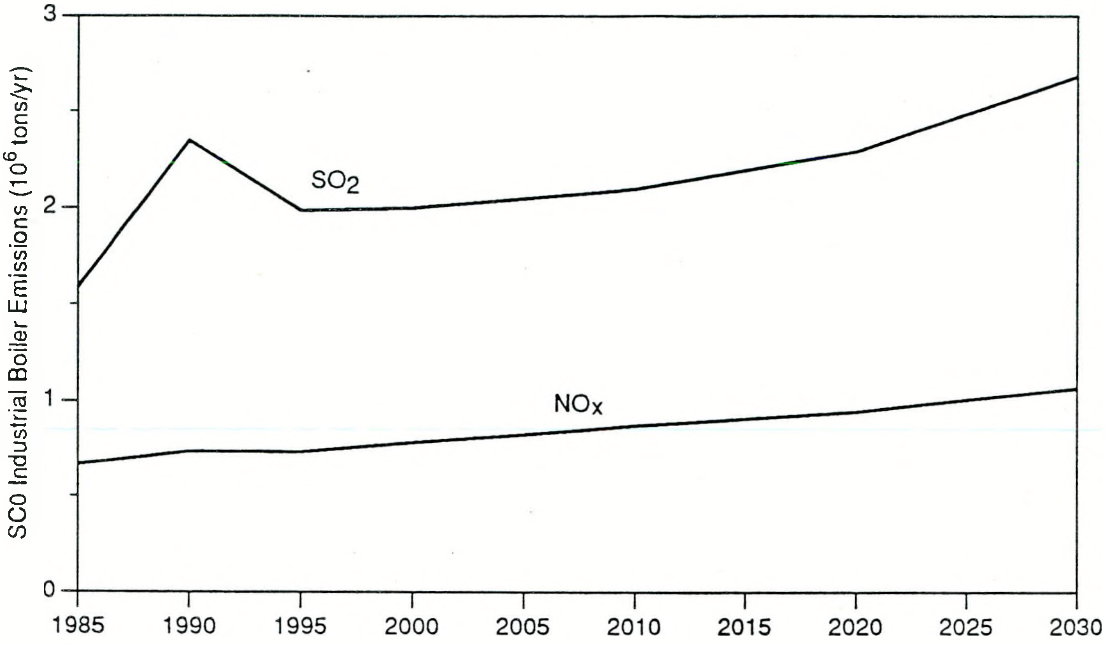

FIGURE 11 ICE Estimates of Boiler SO_2 and NO_x Emissions in SC0

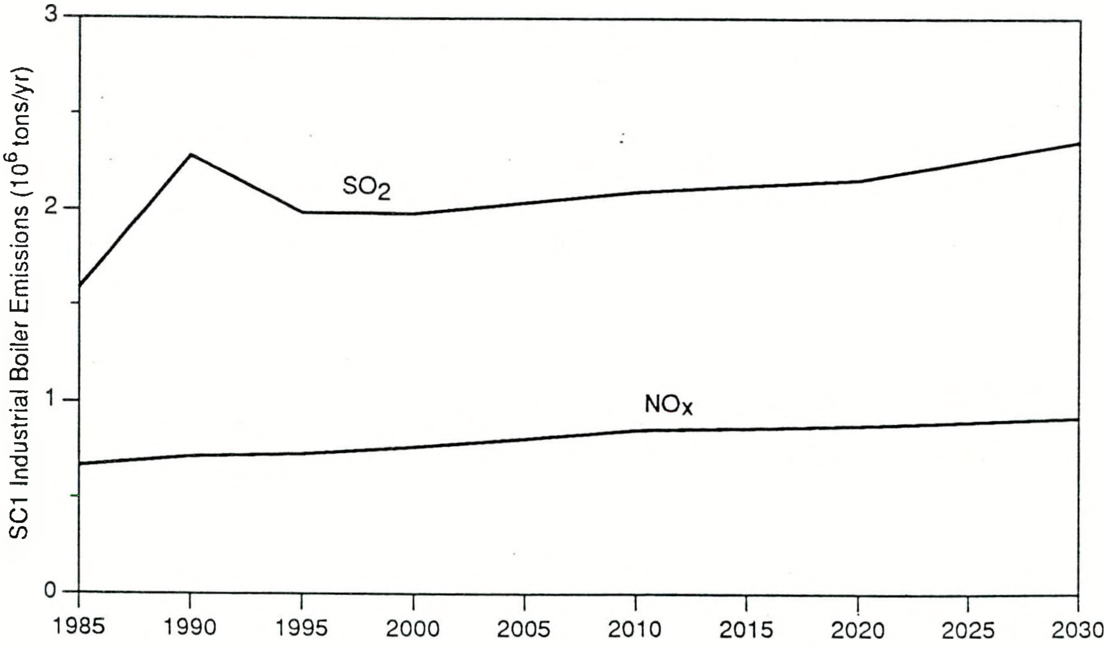

FIGURE 12 ICE Estimates of Boiler SO_2 and NO_x Emissions in SC1

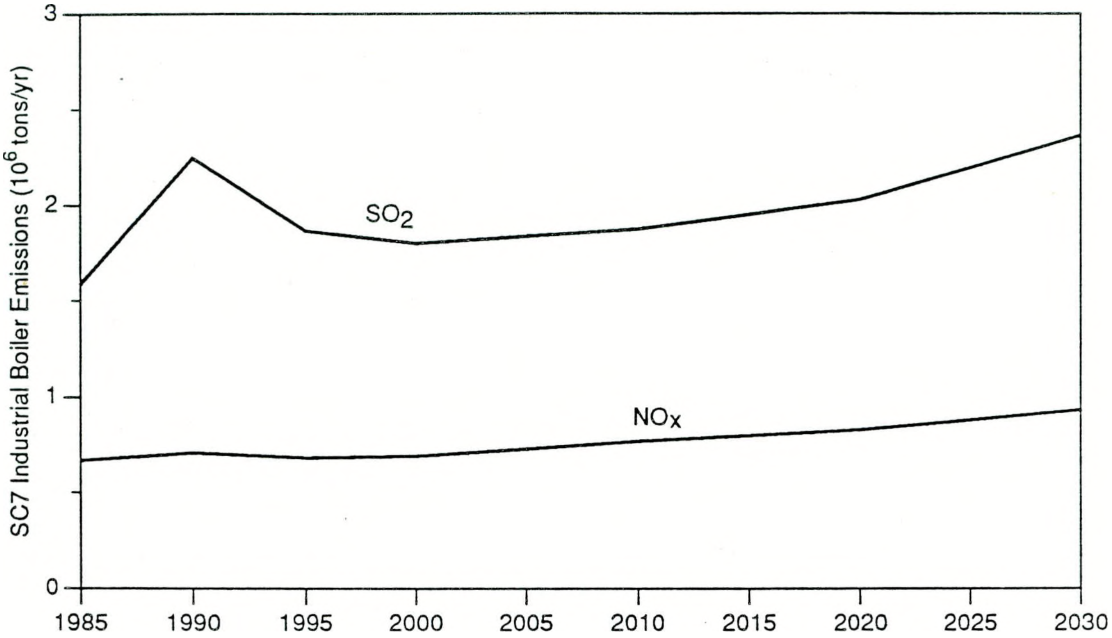

FIGURE 13 ICE Estimates of Boiler SO_2 and NO_x Emissions in SC7

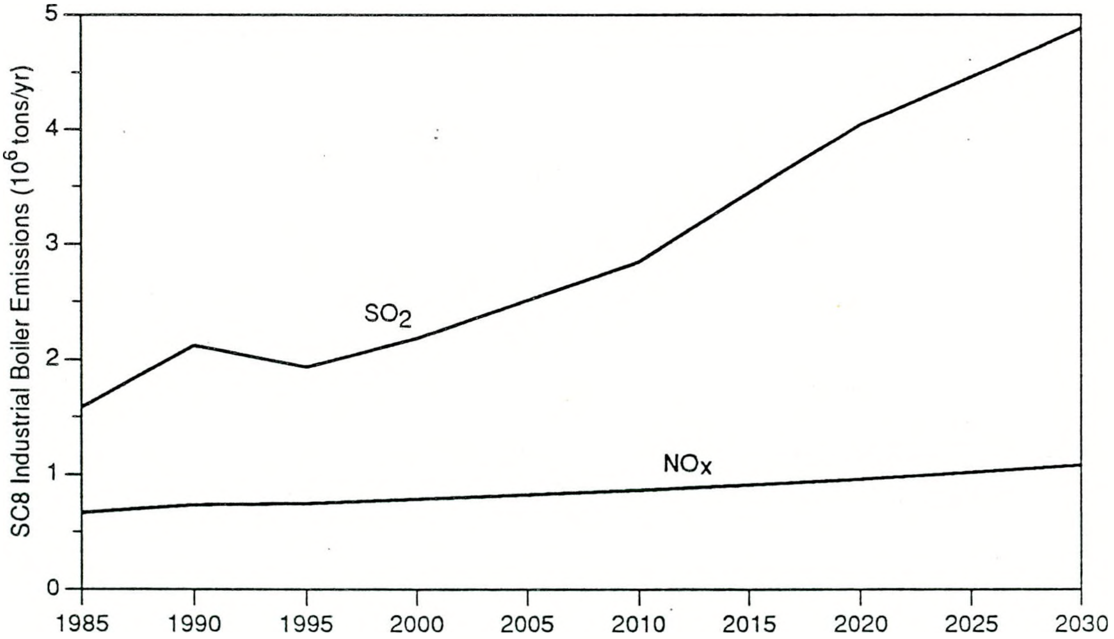

FIGURE 14 ICE Estimates of Boiler SO_2 and NO_x Emissions in SC8

References

American Iron and Steel Institute, 1988, *Annual Statistical Report*, Washington, D.C.

American Paper Institute, 1988, *1988 Statistics of Paper, Paperboard & Wood Pulp: Data through 1987*, New York City.

Blackorby, C., and R.R. Russell, 1989, *Will the Real Elasticity of Substitution Please Stand Up? (A Comparison of the Allen/Uzawa and Morishima Elasticities)*, The American Economic Review, *79*(4):882-888, Sept.

BLS, various dates, *Manufacturer's Shipments, New Order and Inventories (M3), Current Industrial Reports*, Bureau of Labor Statistics, Bureau of the Census, U.S. Department Commerce.

Boyd, G.A., et al., 1990, *Separating the Changing Composition of U.S. Manufacturing Production from Energy Efficiency Improvements: A Divisia Index Approach*, The Energy J., *8*(2):77-96.

Diewert, W.E., 1971, *An Application of the Shephard Duality Theorem: A Generalized Leontief Production Function*, J. of Political Economy, *79*:481-507.

Diewert, W.E., and T.J. Wales, 1987, *Flexible Functional Forms and Global Curvature Conditions*, Econometrica, *55*:43-68, Jan.

DOE, 1979, *Industrial Sector Technology Use Model (ISTUM)*, U.S. Department of Energy Report DOE/FE/2344-1.

EEA, 1989, *Industrial SO_2 Emisson Projections*, report prepared for the U.S. Environmental Protection Agency, by Energy and Environmental Analysis, Inc., Arlington, Va.

Federal Reserve Bulletin, various dates, monthly publication, Board of Governors, Federal Reserve System, Washington, D.C.

Harvey, A.C., 1987, *Time Series Models*, Philip Allan Publishers Ltd., Oxford, England.

Hogan, T., 1988a, *Industrial Combustion Emissions Model (Version 6.0) Software Description*, U.S. Environmental Protection Agency Report EPA-600/8-88-009.

Hogan, T., 1988b, *Industrial Combustion Emissions Model (Version 6.0) User's Manual*, U.S. Environmental Protection Agency Report EPA-600/8-88-007a.

Jack Faucett Associates, Inc., 1984, *National Energy Accounts, 1958-1981*, and current data set from the Office of Business Analysis, U.S. Department of Commerce. Also JACKFAU-84-316, Jack Faucett Associates, Inc., Chevy Chase, Md.

Leontief, W.W., 1941, *The Structure of the American Economy 1919-1929*, Harvard University Press, Cambridge, Mass.

Leontief, W.W., 1947, *Introduction to a Theory of the Internal Structure of Functional Relationships*, Econometrica, *15*:361-373.

Walfridson, B., 1987, *Dynamic Models of Factor Demand: An Application to Swedish Industry*, National Economic Institute, University of Gothenberg, Gothenberg, Sweden.

Bibliography

Ausubel, J.H., and H.E. Sladovich, eds., 1989, *Technology and Environment*, National Academy Press, Washington, D.C.

Berndt, E.R., and D.O. Wood, 1980, *Interindustry Differences in the Effects of Energy Price-Induced Capital Utilization Changes on Multifactor Productivity Measurement*, in J.R. Moroney, ed., Advances in the Economics of Energy and Resources, Vol. 3, JAI Press, Greenwich, Conn.

Healthfield, D.F., and S. Wibe, 1987, *An Introduction to Cost and Production Functions*, MacMillan Education Ltd., London.

Hogan, W.W., 1989, *A Dynamic Putty-Semi-Putty Model of Aggregate Energy Demand*, Energy Economics, *11*:53-69, Jan.

Hsiao, C., 1981, *Autoregressive Modeling and Causal Ordering of Economic Variables*, J. of Economic Dynamics and Control, *4*:243-259.

Moroney, J.R., ed., 1987, *Advances in the Economics of Energy and Resources*, JAI Press, *6*:87-123, Greenwich, Conn., Sept.

Kokkelenberg, E.C., and S.V. Nguyen, 1989, *Modeling Technical Progress and Total Factor Productivity: A Plant Level Example*, The J. of Productivity Analysis, *1*:21-42, April.

Mountain, D., and C. Hsiao, 1989, *A Combined Structural and Flexible Functional Approach for Modeling Energy Substitution*, J. of the American Statistical Assn., *84*:76-87, March.

Ross, M., 1989, *Improving the Efficiency of Electricity Use in Manufacturing*, Science, *244*:311-317, April 21.

Sims, C.A., 1980, *Macroeconomics and Reality*, Econometrica, *48*(1):1-48, Jan.

South, D.W., et al., 1985, *Industrial Volatile Organic Compounds (VOC) Model: Regionalized Projections of Uncontrolled VOC Emissions by Source Category*, Argonne National Laboratory Report ANL/EES-TM-306, June.

Teravirta, T., and I. Mellin, 1989, *Estimation of Polynomial Distributed Lag Models*, mimeo, University of Helsinki, Finland.

Toves, A.L., 1980, *Input Substitution and Biased Technological Change in Resource Intensive Manufacturing Industries*, in J.R. Moroney, ed., Advances in the Economics of Energy and Resources, Vol. 3, JAI Press, Greenwich, Conn.

Appendix A:

ICE Model Runs -- Computer Printouts on Emissions, Costs, and Fossil Fuel Demand for the NAPAP Reference-Case Scenario

base case

INDUSTRIAL BOILER SO2 EMISSIONS (10**3 SHORT TONS)

	BASE (1985)	1990	1995	2000	2010	2020	2030
NEW ENGLAND							
CONN	5.	5.	2.	2.	3.	2.	2.
MAINE	34.	34.	33.	32.	24.	19.	21.
MASS	16.	15.	11.	11.	12.	8.	9.
NH	3.	3.	3.	3.	3.	3.	3.
RI	0.	0.	0.	0.	0.	0.	0.
VT	1.	1.	1.	1.	0.	0.	0.
REGIONAL TOTAL	59.	58.	50.	50.	43.	32.	35.
NEW YORK/NEW JERSEY							
NJ	8.	6.	5.	5.	4.	5.	5.
NY	75.	73.	63.	62.	63.	56.	59.
REGIONAL TOTAL	83.	79.	68.	67.	67.	61.	64.
MIDDLE ATLANTIC							
DEL	9.	8.	8.	8.	8.	8.	9.
MD/DC	13.	13.	12.	13.	13.	12.	13.
PA	48.	53.	52.	54.	55.	55.	60.
VA	88.	93.	87.	90.	99.	107.	121.
WV	47.	44.	42.	42.	41.	44.	46.
REGIONAL TOTAL	204.	210.	200.	207.	216.	226.	249.
SOUTH ATLANTIC							
ALA	36.	43.	44.	41.	54.	78.	94.
FLA	18.	20.	19.	17.	25.	27.	37.
GA	37.	45.	44.	21.	41.	71.	86.
KY	28.	28.	28.	30.	32.	34.	38.
MISS	1.	2.	3.	3.	5.	6.	7.
NC	44.	48.	46.	41.	44.	44.	48.
SC	31.	58.	56.	58.	64.	66.	79.
TENN	43.	56.	53.	53.	61.	66.	79.
REGIONAL TOTAL	237.	300.	294.	264.	326.	393.	468.
MIDWEST							
ILL	71.	132.	130.	133.	90.	103.	145.
IND	110.	165.	162.	166.	164.	163.	175.
MICH	37.	50.	50.	56.	55.	63.	84.
MINN	6.	27.	27.	28.	16.	24.	36.
OHIO	79.	110.	111.	115.	107.	113.	137.
WIS	51.	79.	79.	85.	85.	103.	134.
REGIONAL TOTAL	354.	563.	560.	583.	516.	569.	710.

base case
INDUSTRIAL BOILER SO2 EMISSIONS (10**3 SHORT TONS)

	BASE (1985)	1990	1995	2000	2010	2020	2030
SOUTHWEST							
ARK	5.	16.	17.	19.	25.	29.	34.
LA	26.	75.	86.	113.	179.	231.	288.
NM	0.	0.	0.	0.	0.	0.	0.
OKLA	5.	5.	5.	5.	5.	6.	7.
TX	23.	55.	60.	90.	149.	196.	254.
REGIONAL TOTAL	60.	152.	168.	226.	358.	462.	582.
CENTRAL							
IOWA	44.	60.	63.	66.	68.	68.	70.
KS	3.	43.	45.	48.	57.	57.	60.
MO	9.	30.	31.	35.	31.	37.	46.
NB	1.	2.	3.	3.	2.	2.	3.
REGIONAL TOTAL	57.	136.	142.	152.	158.	164.	179.
NORTH CENTRAL							
COL	3.	3.	3.	3.	3.	3.	3.
MONT	2.	2.	2.	0.	0.	0.	0.
ND	5.	6.	6.	6.	5.	4.	4.
SD	0.	1.	1.	0.	1.	1.	1.
UTAH	2.	2.	2.	2.	3.	3.	3.
WY	16.	15.	14.	14.	13.	13.	12.
REGIONAL TOTAL	29.	28.	27.	25.	25.	23.	23.
WEST							
ARIZ	0.	2.	2.	2.	2.	1.	1.
CAL	7.	16.	18.	23.	25.	31.	37.
NV	1.	1.	1.	1.	2.	2.	2.
REGIONAL TOTAL	8.	20.	21.	26.	28.	33.	40.
NORTHWEST							
ID	3.	4.	4.	4.	4.	5.	5.
OR	2.	3.	3.	3.	5.	5.	7.
WA	5.	6.	6.	4.	6.	5.	6.
REGIONAL TOTAL	11.	13.	13.	11.	15.	15.	17.
LOWER 48 STATES	1101.	1558.	1544.	1610.	1753.	1979.	2367.

base case
INDUSTRIAL BOILER ALLOWABLE SO2 EMISSIONS (10**3 SHORT TONS)

	BASE (1985)	1990	1995	2000	2010	2020	2030
NEW ENGLAND							
CONN	7.	7.	3.	3.	4.	2.	2.
MAINE	48.	101.	33.	32.	24.	19.	21.
MASS	22.	30.	12.	14.	14.	8.	9.
NH	5.	4.	4.	4.	4.	3.	3.
RI	0.	0.	0.	0.	0.	0.	0.
VT	1.	1.	1.	1.	0.	0.	0.
REGIONAL TOTAL	83.	143.	52.	53.	46.	33.	35.
NEW YORK/NEW JERSEY							
NJ	13.	7.	5.	5.	4.	5.	5.
NY	97.	89.	91.	81.	81.	66.	69.
REGIONAL TOTAL	109.	96.	96.	86.	85.	72.	74.
MIDDLE ATLANTIC							
DEL	10.	9.	8.	8.	9.	8.	9.
MD/DC	16.	16.	15.	16.	16.	14.	16.
PA	65.	71.	67.	68.	68.	67.	73.
VA	118.	129.	120.	114.	122.	126.	139.
WV	60.	55.	51.	51.	50.	52.	53.
REGIONAL TOTAL	269.	280.	261.	258.	263.	268.	290.
SOUTH ATLANTIC							
ALA	45.	65.	52.	49.	62.	85.	102.
FLA	24.	34.	20.	18.	28.	28.	38.
GA	42.	62.	65.	24.	44.	74.	88.
KY	45.	45.	46.	46.	47.	48.	51.
MISS	1.	2.	3.	3.	5.	6.	7.
NC	60.	71.	56.	50.	53.	53.	56.
SC	47.	81.	70.	72.	77.	79.	91.
TENN	80.	99.	87.	85.	91.	95.	108.
REGIONAL TOTAL	344.	459.	398.	347.	407.	467.	540.
MIDWEST							
ILL	90.	171.	154.	156.	106.	118.	159.
IND	187.	272.	235.	237.	231.	227.	239.
MICH	51.	67.	64.	70.	65.	73.	93.
MINN	11.	40.	36.	37.	20.	28.	39.
OHIO	107.	177.	149.	145.	129.	135.	159.
WIS	87.	151.	118.	123.	115.	136.	172.
REGIONAL TOTAL	533.	878.	756.	767.	666.	716.	862.

base case
INDUSTRIAL BOILER ALLOWABLE SO2 EMISSIONS (10**3 SHORT TONS)

	BASE (1985)	1990	1995	2000	2010	2020	2030
SOUTHWEST							
ARK	6.	19.	18.	20.	26.	30.	35.
LA	39.	122.	93.	122.	191.	241.	299.
NM	1.	0.	0.	0.	0.	0.	0.
OKLA	7.	8.	6.	6.	6.	7.	8.
TX	29.	62.	61.	92.	152.	198.	258.
REGIONAL TOTAL	81.	211.	179.	241.	376.	476.	601.
CENTRAL							
IOWA	58.	84.	77.	79.	80.	79.	81.
KS	4.	56.	49.	49.	58.	58.	62.
MO	12.	48.	37.	39.	35.	40.	50.
NB	2.	4.	4.	4.	3.	3.	4.
REGIONAL TOTAL	76.	193.	168.	171.	175.	181.	196.
NORTH CENTRAL							
COL	3.	3.	3.	3.	4.	3.	4.
MONT	3.	3.	3.	0.	0.	0.	0.
ND	8.	8.	6.	6.	5.	4.	4.
SD	1.	1.	1.	1.	1.	1.	1.
UTAH	2.	2.	2.	2.	4.	4.	3.
WY	22.	20.	20.	19.	18.	17.	17.
REGIONAL TOTAL	40.	39.	35.	31.	32.	29.	28.
WEST							
ARIZ	0.	4.	2.	2.	2.	1.	1.
CAL	35.	22.	19.	24.	25.	31.	38.
NV	1.	2.	1.	1.	2.	2.	2.
REGIONAL TOTAL	36.	28.	22.	27.	29.	34.	41.
NORTHWEST							
ID	5.	5.	5.	5.	5.	6.	6.
OR	3.	3.	4.	4.	5.	6.	7.
WA	9.	11.	10.	6.	6.	5.	6.
REGIONAL TOTAL	17.	20.	19.	15.	17.	17.	19.
LOWER 48 STATES	1587.	2347.	1986.	1995.	2096.	2291.	2686.

base case

INDUSTRIAL BOILER NOX EMISSIONS (10**3 SHORT TONS)

	BASE (1985)	1990	1995	2000	2010	2020	2030
NEW ENGLAND							
CONN	2.	2.	2.	2.	3.	3.	4.
MAINE	7.	8.	9.	10.	16.	18.	21.
MASS	6.	6.	6.	6.	7.	7.	8.
NH	1.	1.	1.	1.	1.	1.	1.
RI	0.	0.	0.	0.	0.	0.	0.
VT	0.	0.	0.	0.	0.	0.	0.
REGIONAL TOTAL	16.	18.	18.	20.	28.	30.	34.
NEW YORK/NEW JERSEY							
NJ	7.	7.	6.	7.	7.	8.	8.
NY	27.	28.	26.	26.	28.	27.	29.
REGIONAL TOTAL	34.	34.	32.	33.	34.	35.	37.
MIDDLE ATLANTIC							
DEL	3.	3.	3.	3.	3.	4.	4.
MD/DC	9.	9.	9.	9.	10.	10.	10.
PA	28.	29.	28.	29.	29.	29.	31.
VA	37.	39.	38.	40.	44.	47.	53.
WV	22.	23.	23.	23.	24.	24.	25.
REGIONAL TOTAL	99.	103.	101.	105.	110.	114.	123.
SOUTH ATLANTIC							
ALA	22.	24.	24.	27.	33.	39.	46.
FLA	8.	9.	9.	9.	11.	12.	14.
GA	18.	20.	20.	19.	27.	34.	39.
KY	18.	18.	18.	20.	22.	22.	24.
MISS	2.	3.	3.	3.	4.	4.	5.
NC	19.	20.	20.	21.	23.	24.	27.
SC	13.	16.	16.	17.	20.	21.	25.
TENN	21.	23.	22.	22.	24.	25.	29.
REGIONAL TOTAL	122.	133.	132.	138.	163.	182.	210.
MIDWEST							
ILL	42.	45.	45.	45.	43.	48.	55.
IND	43.	48.	47.	48.	47.	47.	49.
MICH	28.	29.	30.	32.	35.	38.	44.
MINN	6.	8.	8.	9.	8.	10.	13.
OHIO	33.	36.	36.	36.	37.	38.	42.
WIS	16.	19.	20.	21.	25.	30.	38.
REGIONAL TOTAL	167.	186.	184.	192.	195.	211.	241.

base case

INDUSTRIAL BOILER NOX EMISSIONS (10**3 SHORT TONS)

	BASE (1985)	1990	1995	2000	2010	2020	2030
SOUTHWEST							
ARK	4.	5.	5.	6.	7.	8.	9.
LA	38.	45.	46.	52.	67.	78.	91.
NM	1.	1.	1.	1.	1.	1.	1.
OKLA	5.	5.	5.	5.	5.	6.	6.
TX	91.	101.	102.	114.	134.	148.	169.
REGIONAL TOTAL	139.	156.	159.	178.	215.	241.	277.
CENTRAL							
IOWA	14.	17.	17.	18.	19.	20.	21.
KS	5.	7.	7.	8.	8.	9.	9.
MO	5.	7.	6.	7.	7.	7.	9.
NB	1.	1.	1.	1.	2.	2.	2.
REGIONAL TOTAL	24.	32.	32.	34.	36.	37.	41.
NORTH CENTRAL							
COL	3.	4.	4.	4.	4.	4.	5.
MONT	1.	1.	1.	1.	1.	1.	1.
ND	1.	2.	2.	2.	2.	2.	2.
SD	0.	0.	0.	0.	0.	0.	0.
UTAH	4.	5.	4.	4.	6.	5.	5.
WY	10.	10.	10.	10.	10.	10.	10.
REGIONAL TOTAL	20.	21.	20.	21.	23.	22.	23.
WEST							
ARIZ	2.	2.	2.	2.	3.	3.	3.
CAL	31.	32.	33.	36.	40.	44.	48.
NV	1.	1.	1.	1.	1.	1.	1.
REGIONAL TOTAL	33.	35.	36.	40.	44.	48.	52.
NORTHWEST							
ID	3.	3.	3.	3.	4.	4.	4.
OR	4.	4.	5.	5.	7.	9.	11.
WA	7.	8.	8.	8.	10.	11.	12.
REGIONAL TOTAL	14.	15.	15.	17.	21.	23.	27.
LOWER 48 STATES	668.	733.	731.	777.	868.	943.	1065.

base case
INDUSTRIAL BOILER SULFATES EMISSIONS (10**3 SHORT TONS)

	BASE (1985)	1990	1995	2000	2010	2020	2030
NEW ENGLAND							
CONN	0.	0.	0.	0.	0.	0.	0.
MAINE	0.	1.	1.	1.	1.	1.	1.
MASS	0.	1.	0.	0.	0.	0.	0.
NH	0.	0.	0.	0.	0.	0.	0.
RI	0.	0.	0.	0.	0.	0.	0.
VT	0.	0.	0.	0.	0.	0.	0.
REGIONAL TOTAL	0.	2.	2.	2.	2.	2.	2.
NEW YORK/NEW JERSEY							
NJ	0.	0.	0.	0.	0.	0.	0.
NY	0.	3.	2.	2.	2.	2.	3.
REGIONAL TOTAL	0.	3.	2.	2.	3.	2.	3.
MIDDLE ATLANTIC							
DEL	0.	0.	0.	0.	0.	0.	0.
MD/DC	0.	0.	0.	0.	1.	1.	1.
PA	0.	2.	2.	2.	2.	2.	3.
VA	0.	5.	5.	5.	6.	6.	7.
WV	0.	1.	1.	2.	2.	2.	2.
REGIONAL TOTAL	0.	9.	9.	9.	10.	11.	13.
SOUTH ATLANTIC							
ALA	0.	1.	1.	2.	3.	4.	5.
FLA	0.	1.	1.	1.	1.	2.	2.
GA	0.	2.	2.	1.	2.	4.	5.
KY	0.	1.	1.	1.	1.	2.	2.
MISS	0.	0.	0.	0.	0.	0.	0.
NC	0.	2.	2.	1.	2.	2.	2.
SC	0.	2.	2.	2.	2.	3.	3.
TENN	0.	2.	2.	2.	2.	3.	4.
REGIONAL TOTAL	0.	10.	10.	10.	14.	20.	25.
MIDWEST							
ILL	0.	5.	4.	5.	4.	5.	7.
IND	0.	6.	6.	6.	6.	6.	7.
MICH	0.	2.	2.	2.	3.	3.	5.
MINN	0.	1.	1.	1.	1.	1.	2.
OHIO	0.	4.	4.	4.	4.	5.	6.
WIS	0.	3.	3.	3.	4.	5.	7.
REGIONAL TOTAL	0.	19.	19.	21.	21.	25.	33.

base case
INDUSTRIAL BOILER SULFATES EMISSIONS (10**3 SHORT TONS)

	BASE (1985)	1990	1995	2000	2010	2020	2030
SOUTHWEST							
ARK	0.	1.	1.	1.	1.	1.	1.
LA	0.	3.	3.	4.	6.	8.	10.
NM	0.	0.	0.	0.	0.	0.	0.
OKLA	0.	0.	0.	0.	0.	0.	0.
TX	0.	2.	2.	3.	5.	7.	9.
REGIONAL TOTAL	0.	5.	6.	8.	12.	15.	20.
CENTRAL							
IOWA	0.	2.	2.	2.	2.	2.	2.
KS	0.	1.	1.	2.	2.	2.	2.
MO	0.	1.	1.	1.	1.	1.	1.
NB	0.	0.	0.	0.	0.	0.	0.
REGIONAL TOTAL	0.	4.	5.	5.	5.	5.	6.
NORTH CENTRAL							
COL	0.	0.	0.	0.	0.	0.	0.
MONT	0.	0.	0.	0.	0.	0.	0.
ND	0.	0.	0.	0.	0.	0.	0.
SD	0.	0.	0.	0.	0.	0.	0.
UTAH	0.	0.	0.	0.	0.	0.	0.
WY	0.	0.	0.	0.	0.	0.	0.
REGIONAL TOTAL	0.	1.	1.	1.	1.	1.	1.
WEST							
ARIZ	0.	0.	0.	0.	0.	0.	0.
CAL	0.	1.	1.	1.	1.	1.	1.
NV	0.	0.	0.	0.	0.	0.	0.
REGIONAL TOTAL	0.	1.	1.	1.	1.	1.	1.
NORTHWEST							
ID	0.	0.	0.	0.	0.	0.	0.
OR	0.	0.	0.	0.	0.	0.	0.
WA	0.	0.	0.	0.	0.	0.	0.
REGIONAL TOTAL	0.	0.	0.	0.	1.	0.	1.
LOWER 48 STATES	0.	55.	54.	59.	69.	83.	103.

base case

INDUSTRIAL BOILER PM EMISSIONS (10**3 SHORT TONS)

	BASE (1985)	1990	1995	2000	2010	2020	2030
NEW ENGLAND							
CONN	1.	1.	0.	0.	1.	1.	1.
MAINE	3.	3.	3.	3.	3.	3.	3.
MASS	1.	1.	1.	1.	1.	1.	1.
NH	0.	0.	0.	0.	0.	0.	0.
RI	0.	0.	0.	0.	0.	0.	0.
VT	0.	0.	0.	0.	0.	0.	0.
REGIONAL TOTAL	5.	5.	5.	5.	6.	5.	6.
NEW YORK/NEW JERSEY							
NJ	1.	1.	1.	1.	1.	1.	1.
NY	8.	8.	7.	7.	7.	7.	7.
REGIONAL TOTAL	9.	9.	8.	8.	8.	8.	8.
MIDDLE ATLANTIC							
DEL	1.	1.	1.	1.	1.	1.	1.
MD/DC	1.	1.	1.	1.	1.	1.	1.
PA	6.	7.	7.	7.	7.	7.	7.
VA	8.	9.	8.	9.	9.	9.	10.
WV	3.	3.	3.	3.	3.	3.	3.
REGIONAL TOTAL	20.	21.	20.	20.	21.	21.	22.
SOUTH ATLANTIC							
ALA	4.	4.	4.	4.	5.	5.	6.
FLA	1.	1.	1.	1.	1.	1.	1.
GA	3.	4.	4.	2.	3.	4.	4.
KY	6.	6.	6.	7.	7.	7.	8.
MISS	0.	0.	1.	1.	1.	1.	1.
NC	5.	6.	6.	5.	6.	6.	6.
SC	5.	7.	8.	8.	9.	11.	12.
TENN	4.	5.	4.	5.	5.	5.	6.
REGIONAL TOTAL	29.	34.	34.	33.	37.	39.	44.
MIDWEST							
ILL	6.	11.	11.	11.	8.	8.	11.
IND	21.	25.	24.	24.	24.	24.	26.
MICH	16.	17.	16.	21.	26.	33.	42.
MINN	1.	3.	3.	3.	2.	3.	4.
OHIO	7.	10.	10.	10.	9.	9.	11.
WIS	3.	5.	5.	5.	4.	5.	6.
REGIONAL TOTAL	53.	70.	69.	74.	74.	82.	100.

base case
INDUSTRIAL BOILER PM EMISSIONS (10**3 SHORT TONS)

	BASE (1985)	1990	1995	2000	2010	2020	2030
SOUTHWEST							
ARK	1.	2.	2.	2.	3.	4.	4.
LA	8.	10.	11.	14.	21.	27.	33.
NM	0.	0.	0.	0.	0.	0.	0.
OKLA	1.	1.	1.	1.	1.	1.	1.
TX	5.	9.	9.	13.	19.	25.	32.
REGIONAL TOTAL	15.	22.	23.	30.	45.	57.	70.
CENTRAL							
IOWA	3.	5.	5.	5.	5.	4.	5.
KS	0.	3.	3.	3.	4.	4.	4.
MO	1.	2.	2.	2.	2.	2.	3.
NB	0.	0.	1.	1.	1.	1.	1.
REGIONAL TOTAL	5.	10.	11.	11.	11.	11.	12.
NORTH CENTRAL							
COL	0.	1.	0.	1.	1.	1.	1.
MONT	0.	0.	0.	0.	0.	0.	0.
ND	0.	1.	1.	1.	1.	0.	1.
SD	0.	0.	0.	0.	0.	0.	0.
UTAH	0.	1.	1.	1.	1.	1.	1.
WY	1.	1.	1.	1.	1.	1.	1.
REGIONAL TOTAL	3.	3.	3.	3.	3.	3.	3.
WEST							
ARIZ	0.	0.	0.	0.	1.	1.	1.
CAL	3.	4.	4.	4.	5.	6.	8.
NV	0.	0.	0.	0.	0.	0.	0.
REGIONAL TOTAL	4.	4.	4.	5.	6.	7.	9.
NORTHWEST							
ID	0.	1.	1.	1.	1.	1.	1.
OR	0.	1.	1.	1.	1.	1.	1.
WA	1.	1.	1.	1.	1.	1.	1.
REGIONAL TOTAL	2.	2.	2.	2.	3.	3.	4.
LOWER 48 STATES	144.	180.	180.	191.	213.	237.	279.

base case

INDUSTRIAL BOILER TOTAL ANNUALIZED COSTS (10**6 1980 $)

	BASE (1985)	1990	1995	2000	2010	2020	2030
NEW ENGLAND							
CONN	0.	72.	81.	110.	159.	174.	218.
MAINE	0.	221.	267.	358.	513.	567.	692.
MASS	0.	189.	214.	283.	395.	430.	495.
NH	0.	23.	29.	37.	56.	65.	85.
RI	0.	6.	6.	8.	9.	8.	8.
VT	0.	7.	8.	11.	15.	17.	21.
REGIONAL TOTAL	0.	518.	604.	808.	1148.	1262.	1519.
NEW YORK/NEW JERSEY							
NJ	0.	204.	229.	293.	413.	428.	475.
NY	0.	608.	650.	811.	1084.	1145.	1361.
REGIONAL TOTAL	0.	811.	879.	1103.	1497.	1573.	1837.
MIDDLE ATLANTIC							
DEL	0.	62.	75.	105.	164.	185.	229.
MD/DC	0.	182.	204.	261.	366.	400.	459.
PA	0.	464.	486.	592.	752.	814.	978.
VA	0.	564.	631.	810.	1172.	1354.	1667.
WV	0.	386.	424.	522.	687.	770.	942.
REGIONAL TOTAL	0.	1657.	1820.	2290.	3141.	3522.	4274.
SOUTH ATLANTIC							
ALA	0.	502.	606.	847.	1331.	1560.	1903.
FLA	0.	193.	222.	308.	499.	570.	707.
GA	0.	446.	536.	690.	1096.	1265.	1519.
KY	0.	335.	374.	474.	664.	739.	889.
MISS	0.	63.	78.	110.	191.	215.	268.
NC	0.	388.	437.	576.	827.	930.	1113.
SC	0.	257.	294.	391.	596.	686.	840.
TENN	0.	374.	399.	505.	761.	867.	1082.
REGIONAL TOTAL	0.	2558.	2945.	3902.	5966.	6831.	8322.
MIDWEST							
ILL	0.	860.	942.	1185.	1660.	1859.	2233.
IND	0.	649.	677.	812.	1065.	1158.	1372.
MICH	0.	539.	635.	835.	1098.	1235.	1519.
MINN	0.	167.	201.	272.	416.	494.	620.
OHIO	0.	590.	646.	796.	1039.	1133.	1338.
WIS	0.	290.	345.	465.	727.	896.	1155.
REGIONAL TOTAL	0.	3096.	3445.	4365.	6005.	6775.	8238.

base case
INDUSTRIAL BOILER TOTAL ANNUALIZED COSTS (10**6 1980 $)

	BASE (1985)	1990	1995	2000	2010	2020	2030
SOUTHWEST							
ARK	0.	88.	105.	138.	219.	263.	327.
LA	0.	1091.	1323.	1873.	3002.	3416.	3996.
NM	0.	42.	45.	62.	89.	91.	103.
OKLA	0.	78.	91.	121.	172.	202.	220.
TX	0.	2127.	2590.	3739.	5747.	6348.	7438.
REGIONAL TOTAL	0.	3427.	4155.	5933.	9230.	10320.	12084.
CENTRAL							
IOWA	0.	292.	328.	436.	643.	717.	897.
KS	0.	101.	117.	164.	240.	261.	306.
MO	0.	105.	118.	165.	250.	273.	346.
NB	0.	34.	43.	58.	91.	107.	138.
REGIONAL TOTAL	0.	532.	607.	822.	1224.	1358.	1686.
NORTH CENTRAL							
COL	0.	63.	75.	107.	164.	187.	226.
MONT	0.	17.	20.	27.	42.	46.	55.
ND	0.	30.	36.	47.	71.	81.	97.
SD	0.	7.	7.	10.	18.	20.	25.
UTAH	0.	96.	100.	127.	164.	156.	179.
WY	0.	221.	230.	272.	359.	364.	436.
REGIONAL TOTAL	0.	435.	470.	589.	818.	854.	1018.
WEST							
ARIZ	0.	53.	67.	92.	149.	161.	219.
CAL	0.	1174.	1395.	1794.	2547.	2859.	3481.
NV	0.	17.	23.	31.	38.	34.	42.
REGIONAL TOTAL	0.	1244.	1485.	1917.	2734.	3054.	3742.
NORTHWEST							
ID	0.	61.	70.	91.	152.	176.	211.
OR	0.	95.	127.	173.	291.	344.	433.
WA	0.	197.	231.	320.	478.	529.	612.
REGIONAL TOTAL	0.	353.	428.	584.	921.	1049.	1257.
LOWER 48 STATES	0.	14631.	16838.	22312.	32684.	36597.	43976.

base case

INDUSTRIAL BOILER FOSSIL FUEL DEMAND, 1985 (10**12 BTUS)
ALL BOILERS

	NAT. GAS	DIST.	RESID	COAL	TOTAL
NEW ENGLAND					
CONN	3.	0.	13.	0.	17.
MAINE	0.	0.	52.	0.	52.
MASS	13.	0.	30.	2.	45.
NH	0.	0.	4.	0.	4.
RI	1.	0.	0.	0.	1.
VT	1.	0.	1.	0.	2.
REGIONAL TOTAL	18.	0.	101.	2.	121.
NEW YORK/NEW JERSEY					
NJ	26.	4.	28.	0.	59.
NY	25.	5.	80.	43.	152.
REGIONAL TOTAL	51.	9.	108.	43.	211.
MIDDLE ATLANTIC					
DEL	4.	1.	5.	4.	14.
MD/DC	26.	4.	7.	13.	50.
PA	25.	2.	14.	70.	110.
VA	23.	4.	18.	83.	128.
WV	20.	0.	8.	63.	91.
REGIONAL TOTAL	98.	11.	52.	232.	393.
SOUTH ATLANTIC					
ALA	56.	17.	24.	37.	133.
FLA	19.	4.	20.	9.	52.
GA	61.	3.	48.	10.	123.
KY	20.	0.	3.	49.	72.
MISS	17.	0.	1.	0.	18.
NC	18.	6.	32.	38.	95.
SC	22.	2.	13.	27.	64.
TENN	39.	4.	7.	46.	97.
REGIONAL TOTAL	253.	36.	149.	215.	652.
MIDWEST					
ILL	111.	28.	22.	65.	226.
IND	42.	2.	5.	99.	147.
MICH	81.	2.	10.	53.	146.
MINN	29.	0.	2.	6.	37.
OHIO	49.	4.	19.	77.	148.
WIS	33.	0.	3.	36.	72.
REGIONAL TOTAL	345.	36.	61.	335.	776.

```
           base case
      INDUSTRIAL BOILER FOSSIL FUEL DEMAND, 1985 (10**12 BTUS)
                                    ALL BOILERS

                          NAT. GAS      DIST.      RESID       COAL      TOTAL
SOUTHWEST
  ARK                           7.         0.         4.         8.        18.
  LA                          255.         6.        51.         9.       321.
  NM                            8.         0.         2.         0.        10.
  OKLA                         20.         0.         2.         9.        31.
  TX                          655.        11.        22.         2.       690.
REGIONAL TOTAL                946.        16.        81.        28.      1070.

CENTRAL
  IOWA                         31.         1.         1.        29.        62.
  KS                           29.         0.         1.         1.        32.
  MO                           25.         0.         0.         5.        30.
  NB                            7.         0.         0.         1.         9.
REGIONAL TOTAL                 92.         1.         2.        37.       134.

NORTH CENTRAL
  COL                           9.         0.         0.         7.        16.
  MONT                          6.         0.         3.         0.         9.
  ND                            0.         0.         5.         2.         7.
  SD                            1.         0.         0.         0.         1.
  UTAH                         24.         0.         0.         3.        27.
  WY                           23.         0.         7.        20.        50.
REGIONAL TOTAL                 62.         0.        15.        32.       110.

WEST
  ARIZ                         14.         0.         0.         1.        14.
  CAL                         127.         7.       126.         0.       260.
  NV                            3.         0.         0.         1.         4.
REGIONAL TOTAL                143.         7.       126.         2.       279.

NORTHWEST
  ID                           11.         0.         0.         7.        18.
  OR                           21.         0.         3.         2.        26.
  WA                           41.         0.        13.         0.        53.
REGIONAL TOTAL                 73.         0.        15.         9.        97.


LOWER  48 STATES             2081.       117.       710.       936.      3843.
```

base case
INDUSTRIAL BOILER FOSSIL FUEL DEMAND, 1990 (10**12 BTUS)
ALL BOILERS

	NAT. GAS	DIST.	RESID	COAL	TOTAL
NEW ENGLAND					
CONN	7.	0.	13.	1.	20.
MAINE	11.	0.	50.	2.	64.
MASS	21.	0.	25.	3.	49.
NH	1.	0.	4.	1.	6.
RI	1.	0.	0.	0.	2.
VT	1.	0.	1.	0.	2.
REGIONAL TOTAL	42.	0.	94.	7.	142.
NEW YORK/NEW JERSEY					
NJ	52.	0.	11.	1.	64.
NY	56.	0.	69.	45.	171.
REGIONAL TOTAL	108.	0.	80.	46.	235.
MIDDLE ATLANTIC					
DEL	12.	0.	2.	4.	18.
MD/DC	37.	0.	7.	13.	57.
PA	45.	0.	15.	69.	129.
VA	58.	0.	22.	85.	165.
WV	46.	0.	5.	62.	113.
REGIONAL TOTAL	197.	0.	51.	233.	481.
SOUTH ATLANTIC					
ALA	105.	0.	26.	36.	167.
FLA	34.	0.	18.	11.	64.
GA	102.	0.	38.	14.	153.
KY	35.	0.	4.	47.	86.
MISS	20.	0.	2.	1.	23.
NC	47.	0.	34.	38.	119.
SC	28.	0.	28.	28.	84.
TENN	61.	0.	15.	44.	120.
REGIONAL TOTAL	432.	0.	165.	219.	816.
MIDWEST					
ILL	71.	0.	123.	68.	263.
IND	21.	0.	59.	98.	178.
MICH	73.	0.	46.	51.	170.
MINN	8.	0.	33.	7.	48.
OHIO	31.	0.	66.	76.	174.
WIS	10.	0.	43.	37.	90.
REGIONAL TOTAL	214.	0.	370.	339.	923.

base case
INDUSTRIAL BOILER FOSSIL FUEL DEMAND, 1990 (10**12 BTUS)
ALL BOILERS

	NAT. GAS	DIST.	RESID	COAL	TOTAL
SOUTHWEST					
ARK	10.	0.	5.	11.	26.
LA	316.	0.	53.	13.	383.
NM	12.	0.	0.	1.	13.
OKLA	17.	0.	1.	9.	27.
TX	760.	0.	26.	17.	803.
REGIONAL TOTAL	1115.	0.	86.	50.	1251.
CENTRAL					
IOWA	31.	0.	23.	32.	86.
KS	8.	0.	27.	3.	38.
MO	11.	0.	20.	6.	37.
NB	7.	0.	2.	2.	11.
REGIONAL TOTAL	58.	0.	72.	42.	171.
NORTH CENTRAL					
COL	12.	0.	0.	7.	19.
MONT	4.	0.	2.	0.	6.
ND	1.	0.	6.	2.	9.
SD	0.	0.	1.	0.	2.
UTAH	30.	0.	0.	3.	34.
WY	35.	0.	3.	22.	60.
REGIONAL TOTAL	83.	0.	12.	34.	129.
WEST					
ARIZ	13.	0.	4.	1.	18.
CAL	282.	0.	30.	10.	322.
NV	3.	0.	1.	1.	6.
REGIONAL TOTAL	298.	0.	36.	12.	345.
NORTHWEST					
ID	10.	0.	0.	7.	18.
OR	27.	0.	3.	2.	32.
WA	53.	0.	13.	1.	67.
REGIONAL TOTAL	90.	0.	17.	9.	116.
LOWER 48 STATES	2637.	0.	982.	992.	4611.

base case
INDUSTRIAL BOILER FOSSIL FUEL DEMAND, 1995 (10**12 BTUS)
ALL BOILERS

	NAT. GAS	DIST.	RESID	COAL	TOTAL
NEW ENGLAND					
CONN	14.	0.	5.	1.	20.
MAINE	14.	0.	48.	5.	67.
MASS	28.	0.	17.	4.	49.
NH	1.	0.	4.	1.	7.
RI	1.	0.	0.	0.	1.
VT	1.	0.	1.	0.	2.
REGIONAL TOTAL	60.	0.	75.	11.	146.
NEW YORK/NEW JERSEY					
NJ	58.	0.	5.	1.	64.
NY	84.	0.	37.	45.	166.
REGIONAL TOTAL	142.	0.	42.	46.	230.
MIDDLE ATLANTIC					
DEL	12.	0.	2.	4.	19.
MD/DC	38.	0.	6.	13.	57.
PA	45.	0.	14.	67.	126.
VA	70.	0.	17.	84.	171.
WV	51.	0.	0.	62.	113.
REGIONAL TOTAL	216.	0.	39.	230.	486.
SOUTH ATLANTIC					
ALA	113.	0.	26.	36.	175.
FLA	37.	0.	18.	11.	65.
GA	106.	0.	36.	15.	157.
KY	36.	0.	3.	47.	87.
MISS	20.	0.	2.	2.	23.
NC	51.	0.	32.	38.	121.
SC	31.	0.	27.	28.	86.
TENN	59.	0.	13.	43.	116.
REGIONAL TOTAL	454.	0.	158.	219.	830.
MIDWEST					
ILL	71.	0.	121.	67.	259.
IND	22.	0.	60.	95.	177.
MICH	75.	0.	45.	52.	171.
MINN	11.	0.	33.	8.	51.
OHIO	30.	0.	68.	75.	173.
WIS	13.	0.	44.	38.	95.
REGIONAL TOTAL	222.	0.	369.	335.	927.

base case
INDUSTRIAL BOILER FOSSIL FUEL DEMAND, 1995 (10**12 BTUS)
ALL BOILERS

	NAT. GAS	DIST.	RESID	COAL	TOTAL
SOUTHWEST					
ARK	11.	0.	5.	11.	28.
LA	321.	0.	56.	16.	393.
NM	12.	0.	0.	1.	13.
OKLA	18.	0.	1.	8.	27.
TX	769.	0.	28.	21.	819.
REGIONAL TOTAL	1131.	0.	91.	58.	1281.
CENTRAL					
IOWA	29.	0.	25.	33.	87.
KS	8.	0.	28.	3.	38.
MO	9.	0.	21.	6.	36.
NB	6.	0.	3.	2.	11.
REGIONAL TOTAL	53.	0.	77.	43.	173.
NORTH CENTRAL					
COL	13.	0.	0.	7.	20.
MONT	4.	0.	2.	0.	6.
ND	2.	0.	6.	2.	10.
SD	1.	0.	1.	0.	2.
UTAH	28.	0.	0.	3.	31.
WY	36.	0.	3.	21.	59.
REGIONAL TOTAL	84.	0.	11.	34.	129.
WEST					
ARIZ	14.	0.	4.	1.	19.
CAL	288.	0.	30.	12.	330.
NV	3.	0.	1.	1.	6.
REGIONAL TOTAL	305.	0.	36.	14.	355.
NORTHWEST					
ID	11.	0.	0.	7.	18.
OR	28.	0.	3.	4.	34.
WA	55.	0.	11.	1.	68.
REGIONAL TOTAL	93.	0.	15.	12.	120.
LOWER 48 STATES	2760.	0.	914.	1002.	4676.

base case

INDUSTRIAL BOILER FOSSIL FUEL DEMAND, 2000 (10**12 BTUS)
ALL BOILERS

	NAT. GAS	DIST.	RESID	COAL	TOTAL
NEW ENGLAND					
CONN	16.	0.	5.	1.	22.
MAINE	18.	0.	46.	9.	73.
MASS	31.	0.	16.	6.	54.
NH	2.	0.	4.	1.	7.
RI	1.	0.	0.	0.	1.
VT	1.	0.	1.	0.	2.
REGIONAL TOTAL	70.	0.	72.	18.	159.
NEW YORK/NEW JERSEY					
NJ	60.	0.	5.	1.	66.
NY	94.	0.	36.	45.	175.
REGIONAL TOTAL	154.	0.	41.	47.	241.
MIDDLE ATLANTIC					
DEL	16.	0.	0.	5.	21.
MD/DC	40.	0.	6.	14.	60.
PA	59.	0.	7.	68.	133.
VA	86.	0.	16.	87.	190.
WV	59.	0.	0.	63.	122.
REGIONAL TOTAL	260.	0.	30.	236.	526.
SOUTH ATLANTIC					
ALA	141.	0.	13.	46.	199.
FLA	49.	0.	13.	11.	73.
GA	145.	0.	8.	17.	170.
KY	45.	0.	3.	51.	98.
MISS	23.	0.	2.	3.	27.
NC	68.	0.	24.	40.	133.
SC	42.	0.	25.	29.	96.
TENN	71.	0.	13.	42.	126.
REGIONAL TOTAL	584.	0.	100.	239.	923.
MIDWEST					
ILL	82.	0.	122.	68.	272.
IND	30.	0.	63.	94.	187.
MICH	84.	0.	44.	59.	187.
MINN	16.	0.	33.	8.	57.
OHIO	37.	0.	70.	76.	183.
WIS	21.	0.	46.	41.	107.
REGIONAL TOTAL	271.	0.	377.	346.	994.

base case
INDUSTRIAL BOILER FOSSIL FUEL DEMAND, 2000 (10**12 BTUS)
ALL BOILERS

	NAT. GAS	DIST.	RESID	COAL	TOTAL
SOUTHWEST					
ARK	14.	0.	6.	11.	32.
LA	351.	0.	61.	26.	438.
NM	13.	0.	0.	1.	14.
OKLA	20.	0.	1.	8.	30.
TX	820.	0.	34.	50.	903.
REGIONAL TOTAL	1219.	0.	102.	96.	1417.
CENTRAL					
IOWA	38.	0.	26.	34.	98.
KS	10.	0.	28.	3.	42.
MO	11.	0.	22.	7.	40.
NB	8.	0.	3.	2.	12.
REGIONAL TOTAL	67.	0.	79.	45.	191.
NORTH CENTRAL					
COL	16.	0.	0.	7.	23.
MONT	6.	0.	0.	0.	6.
ND	3.	0.	6.	2.	11.
SD	1.	0.	0.	0.	2.
UTAH	30.	0.	0.	3.	33.
WY	39.	0.	3.	21.	63.
REGIONAL TOTAL	95.	0.	9.	34.	138.
WEST					
ARIZ	16.	0.	4.	1.	21.
CAL	313.	0.	29.	21.	363.
NV	4.	0.	1.	1.	7.
REGIONAL TOTAL	333.	0.	35.	23.	391.
NORTHWEST					
ID	13.	0.	0.	7.	20.
OR	31.	0.	2.	6.	39.
WA	65.	0.	6.	3.	74.
REGIONAL TOTAL	109.	0.	9.	16.	133.
LOWER 48 STATES	3161.	0.	852.	1099.	5113.

base case
INDUSTRIAL BOILER FOSSIL FUEL DEMAND, 2010 (10**12 BTUS)
ALL BOILERS

	NAT. GAS	DIST.	RESID	COAL	TOTAL
NEW ENGLAND					
CONN	14.	0.	5.	6.	25.
MAINE	25.	0.	24.	34.	83.
MASS	32.	0.	15.	10.	58.
NH	3.	0.	4.	2.	9.
RI	1.	0.	0.	0.	1.
VT	2.	0.	1.	0.	2.
REGIONAL TOTAL	77.	0.	48.	53.	178.
NEW YORK/NEW JERSEY					
NJ	61.	0.	3.	3.	67.
NY	97.	0.	33.	51.	181.
REGIONAL TOTAL	158.	0.	35.	55.	248.
MIDDLE ATLANTIC					
DEL	19.	0.	0.	6.	25.
MD/DC	43.	0.	6.	15.	64.
PA	62.	0.	7.	70.	139.
VA	102.	0.	15.	99.	216.
WV	69.	0.	0.	61.	130.
REGIONAL TOTAL	295.	0.	28.	251.	574.
SOUTH ATLANTIC					
ALA	161.	0.	14.	58.	233.
FLA	55.	0.	12.	17.	84.
GA	136.	0.	8.	44.	189.
KY	58.	0.	2.	54.	114.
MISS	26.	0.	2.	5.	32.
NC	77.	0.	23.	46.	146.
SC	47.	0.	26.	36.	109.
TENN	80.	0.	14.	47.	141.
REGIONAL TOTAL	639.	0.	101.	306.	1046.
MIDWEST					
ILL	178.	0.	39.	76.	293.
IND	53.	0.	51.	94.	198.
MICH	115.	0.	13.	72.	200.
MINN	46.	0.	10.	10.	67.
OHIO	80.	0.	31.	81.	192.
WIS	54.	0.	17.	58.	130.
REGIONAL TOTAL	526.	0.	161.	393.	1080.

base case

INDUSTRIAL BOILER FOSSIL FUEL DEMAND, 2010 (10**12 BTUS)

ALL BOILERS

	NAT. GAS	DIST.	RESID	COAL	TOTAL
SOUTHWEST					
ARK	17.	0.	7.	15.	39.
LA	364.	0.	78.	60.	502.
NM	14.	0.	0.	1.	14.
OKLA	22.	0.	1.	9.	32.
TX	836.	0.	37.	120.	993.
REGIONAL TOTAL	1252.	0.	123.	205.	1580.
CENTRAL					
IOWA	59.	0.	15.	38.	113.
KS	10.	0.	28.	6.	44.
MO	22.	0.	14.	8.	44.
NB	11.	0.	2.	2.	14.
REGIONAL TOTAL	102.	0.	59.	54.	214.
NORTH CENTRAL					
COL	18.	0.	0.	9.	27.
MONT	7.	0.	0.	0.	7.
ND	5.	0.	5.	2.	12.
SD	1.	0.	0.	1.	2.
UTAH	22.	0.	0.	11.	33.
WY	40.	0.	2.	21.	64.
REGIONAL TOTAL	93.	0.	7.	44.	145.
WEST					
ARIZ	20.	0.	2.	2.	24.
CAL	353.	0.	13.	34.	400.
NV	4.	0.	0.	3.	7.
REGIONAL TOTAL	377.	0.	16.	39.	431.
NORTHWEST					
ID	17.	0.	0.	7.	25.
OR	32.	0.	2.	12.	46.
WA	64.	0.	6.	10.	80.
REGIONAL TOTAL	113.	0.	8.	30.	151.
LOWER 48 STATES	3632.	0.	587.	1428.	5647.

base case

INDUSTRIAL BOILER FOSSIL FUEL DEMAND, 2020 (10**12 BTUS)

ALL BOILERS

	NAT. GAS	DIST.	RESID	COAL	TOTAL
NEW ENGLAND					
CONN	20.	0.	0.	6.	26.
MAINE	38.	0.	11.	43.	91.
MASS	42.	0.	5.	13.	60.
NH	5.	0.	3.	2.	10.
RI	1.	0.	0.	0.	1.
VT	2.	0.	1.	0.	2.
REGIONAL TOTAL	108.	0.	19.	64.	191.
NEW YORK/NEW JERSEY					
NJ	53.	0.	2.	10.	65.
NY	113.	0.	16.	55.	183.
REGIONAL TOTAL	165.	0.	18.	65.	248.
MIDDLE ATLANTIC					
DEL	20.	0.	0.	7.	27.
MD/DC	48.	0.	0.	17.	65.
PA	66.	0.	7.	69.	142.
VA	115.	0.	9.	110.	234.
WV	72.	0.	0.	63.	136.
REGIONAL TOTAL	321.	0.	16.	266.	604.
SOUTH ATLANTIC					
ALA	166.	0.	11.	79.	256.
FLA	64.	0.	7.	20.	90.
GA	130.	0.	6.	69.	205.
KY	63.	0.	2.	55.	120.
MISS	27.	0.	2.	6.	34.
NC	87.	0.	15.	52.	154.
SC	53.	0.	23.	42.	118.
TENN	84.	0.	16.	50.	150.
REGIONAL TOTAL	673.	0.	80.	374.	1127.
MIDWEST					
ILL	178.	0.	34.	94.	305.
IND	61.	0.	48.	93.	202.
MICH	118.	0.	7.	85.	210.
MINN	47.	0.	10.	17.	74.
OHIO	83.	0.	27.	86.	196.
WIS	58.	0.	19.	73.	150.
REGIONAL TOTAL	545.	0.	145.	448.	1138.

base case
INDUSTRIAL BOILER FOSSIL FUEL DEMAND, 2020 (10**12 BTUS)
ALL BOILERS

	NAT. GAS	DIST.	RESID	COAL	TOTAL
SOUTHWEST					
ARK	20.	0.	8.	16.	44.
LA	371.	0.	80.	93.	544.
NM	13.	0.	0.	1.	14.
OKLA	21.	0.	1.	12.	33.
TX	829.	0.	35.	177.	1042.
REGIONAL TOTAL	1255.	0.	124.	298.	1677.
CENTRAL					
IOWA	69.	0.	7.	43.	118.
KS	11.	0.	27.	6.	44.
MO	24.	0.	11.	10.	45.
NB	13.	0.	1.	2.	16.
REGIONAL TOTAL	117.	0.	46.	61.	223.
NORTH CENTRAL					
COL	20.	0.	0.	9.	29.
MONT	6.	0.	0.	0.	7.
ND	7.	0.	4.	2.	13.
SD	2.	0.	0.	1.	3.
UTAH	20.	0.	0.	10.	30.
WY	39.	0.	2.	20.	62.
REGIONAL TOTAL	95.	0.	6.	43.	144.
WEST					
ARIZ	23.	0.	0.	2.	25.
CAL	367.	0.	13.	47.	427.
NV	3.	0.	0.	3.	6.
REGIONAL TOTAL	394.	0.	13.	52.	458.
NORTHWEST					
ID	18.	0.	0.	9.	27.
OR	36.	0.	1.	16.	53.
WA	68.	0.	2.	14.	83.
REGIONAL TOTAL	123.	0.	3.	39.	164.
LOWER 48 STATES	3796.	0.	470.	1709.	5975.

base case
INDUSTRIAL BOILER FOSSIL FUEL DEMAND, 2030 (10**12 BTUS)
ALL BOILERS

	NAT. GAS	DIST.	RESID	COAL	TOTAL
NEW ENGLAND					
CONN	21.	0.	0.	8.	30.
MAINE	44.	0.	10.	52.	106.
MASS	45.	0.	5.	16.	66.
NH	6.	0.	3.	3.	12.
RI	1.	0.	0.	0.	1.
VT	2.	0.	0.	0.	2.
REGIONAL TOTAL	119.	0.	18.	79.	216.
NEW YORK/NEW JERSEY					
NJ	52.	0.	2.	11.	65.
NY	123.	0.	15.	60.	197.
REGIONAL TOTAL	174.	0.	17.	71.	263.
MIDDLE ATLANTIC					
DEL	23.	0.	0.	8.	30.
MD/DC	49.	0.	0.	19.	68.
PA	74.	0.	10.	71.	155.
VA	128.	0.	9.	127.	263.
WV	85.	0.	0.	65.	150.
REGIONAL TOTAL	359.	0.	19.	288.	666.
SOUTH ATLANTIC					
ALA	175.	0.	13.	98.	286.
FLA	67.	0.	6.	28.	101.
GA	135.	0.	5.	85.	226.
KY	69.	0.	1.	61.	131.
MISS	29.	0.	1.	8.	38.
NC	95.	0.	14.	59.	168.
SC	55.	0.	26.	51.	132.
TENN	92.	0.	18.	58.	168.
REGIONAL TOTAL	717.	0.	86.	448.	1251.
MIDWEST					
ILL	142.	0.	80.	107.	328.
IND	59.	0.	59.	96.	214.
MICH	108.	0.	20.	104.	231.
MINN	42.	0.	21.	21.	84.
OHIO	59.	0.	56.	92.	208.
WIS	47.	0.	39.	90.	176.
REGIONAL TOTAL	457.	0.	274.	510.	1242.

base case
INDUSTRIAL BOILER FOSSIL FUEL DEMAND, 2030 (10**12 BTUS)
ALL BOILERS

	NAT. GAS	DIST.	RESID	COAL	TOTAL
SOUTHWEST					
ARK	23.	0.	9.	18.	51.
LA	387.	0.	95.	121.	603.
NM	13.	0.	0.	1.	14.
OKLA	21.	0.	1.	13.	35.
TX	858.	0.	42.	239.	1139.
REGIONAL TOTAL	1303.	0.	147.	391.	1842.
CENTRAL					
IOWA	77.	0.	10.	45.	132.
KS	11.	0.	28.	6.	46.
MO	20.	0.	17.	12.	50.
NB	14.	0.	1.	3.	18.
REGIONAL TOTAL	122.	0.	56.	67.	245.
NORTH CENTRAL					
COL	22.	0.	0.	10.	32.
MONT	7.	0.	0.	0.	7.
ND	8.	0.	3.	2.	13.
SD	2.	0.	0.	1.	3.
UTAH	20.	0.	0.	10.	30.
WY	43.	0.	2.	21.	66.
REGIONAL TOTAL	102.	0.	6.	44.	151.
WEST					
ARIZ	24.	0.	0.	4.	29.
CAL	387.	0.	14.	59.	461.
NV	3.	0.	0.	3.	6.
REGIONAL TOTAL	415.	0.	14.	67.	496.
NORTHWEST					
ID	21.	0.	0.	9.	30.
OR	39.	0.	1.	22.	62.
WA	71.	0.	2.	18.	90.
REGIONAL TOTAL	131.	0.	3.	49.	183.
LOWER 48 STATES	3899.	0.	641.	2014.	6555.

base case
INDUSTRIAL BOILER FOSSIL FUEL DEMAND, 1990 (10**12 BTUS)
BOILERS BUILT SINCE PREVIOUS RUN YEAR

	NAT. GAS	DIST.	RESID	COAL	TOTAL
NEW ENGLAND					
CONN	3.	0.	0.	1.	4.
MAINE	11.	0.	0.	2.	14.
MASS	5.	0.	0.	1.	6.
NH	1.	0.	0.	1.	2.
RI	0.	0.	0.	0.	0.
VT	0.	0.	0.	0.	0.
REGIONAL TOTAL	20.	0.	0.	5.	25.
NEW YORK/NEW JERSEY					
NJ	7.	0.	0.	1.	8.
NY	19.	0.	0.	4.	23.
REGIONAL TOTAL	26.	0.	0.	4.	31.
MIDDLE ATLANTIC					
DEL	5.	0.	0.	0.	5.
MD/DC	8.	0.	0.	0.	9.
PA	19.	0.	1.	2.	22.
VA	38.	0.	0.	4.	43.
WV	23.	0.	0.	1.	24.
REGIONAL TOTAL	93.	0.	1.	8.	102.
SOUTH ATLANTIC					
ALA	31.	0.	7.	0.	38.
FLA	11.	0.	0.	3.	13.
GA	26.	0.	4.	4.	34.
KY	20.	0.	2.	0.	21.
MISS	3.	0.	1.	1.	5.
NC	23.	0.	4.	1.	27.
SC	15.	0.	6.	1.	22.
TENN	22.	0.	4.	0.	27.
REGIONAL TOTAL	151.	0.	27.	10.	188.
MIDWEST					
ILL	1.	0.	38.	5.	43.
IND	0.	0.	34.	2.	35.
MICH	7.	0.	21.	0.	28.
MINN	0.	0.	10.	2.	13.
OHIO	0.	0.	28.	2.	30.
WIS	0.	0.	18.	2.	20.
REGIONAL TOTAL	9.	0.	148.	13.	170.

base case
INDUSTRIAL BOILER FOSSIL FUEL DEMAND, 1990 (10**12 BTUS)
BOILERS BUILT SINCE PREVIOUS RUN YEAR

	NAT. GAS	DIST.	RESID	COAL	TOTAL
SOUTHWEST					
ARK	3.	0.	2.	4.	8.
LA	53.	0.	14.	4.	71.
NM	2.	0.	0.	1.	3.
OKLA	3.	0.	0.	0.	3.
TX	113.	0.	6.	15.	134.
REGIONAL TOTAL	174.	0.	22.	23.	219.
CENTRAL					
IOWA	1.	0.	20.	4.	25.
KS	0.	0.	6.	1.	7.
MO	0.	0.	7.	1.	8.
NB	0.	0.	2.	0.	2.
REGIONAL TOTAL	1.	0.	34.	6.	42.
NORTH CENTRAL					
COL	4.	0.	0.	0.	4.
MONT	0.	0.	0.	0.	0.
ND	1.	0.	1.	0.	3.
SD	0.	0.	0.	0.	1.
UTAH	8.	0.	0.	0.	8.
WY	12.	0.	0.	3.	15.
REGIONAL TOTAL	26.	0.	1.	4.	31.
WEST					
ARIZ	1.	0.	3.	0.	4.
CAL	51.	0.	9.	10.	69.
NV	0.	0.	1.	0.	2.
REGIONAL TOTAL	52.	0.	13.	10.	75.
NORTHWEST					
ID	4.	0.	0.	0.	5.
OR	6.	0.	1.	0.	7.
WA	14.	0.	1.	1.	15.
REGIONAL TOTAL	24.	0.	2.	1.	27.
LOWER 48 STATES	576.	0.	251.	83.	910.

base case

INDUSTRIAL BOILER FOSSIL FUEL DEMAND, 1995 (10**12 BTUS)

BOILERS BUILT SINCE PREVIOUS RUN YEAR

	NAT. GAS	DIST.	RESID	COAL	TOTAL
NEW ENGLAND					
CONN	1.	0.	0.	0.	1.
MAINE	3.	0.	0.	2.	5.
MASS	1.	0.	0.	1.	2.
NH	0.	0.	0.	1.	1.
RI	0.	0.	0.	0.	0.
VT	0.	0.	0.	0.	0.
REGIONAL TOTAL	6.	0.	0.	4.	9.
NEW YORK/NEW JERSEY					
NJ	1.	0.	0.	0.	1.
NY	2.	0.	0.	1.	3.
REGIONAL TOTAL	3.	0.	0.	1.	4.
MIDDLE ATLANTIC					
DEL	0.	0.	0.	1.	1.
MD/DC	1.	0.	0.	0.	1.
PA	2.	0.	0.	0.	3.
VA	8.	0.	0.	2.	10.
WV	2.	0.	0.	1.	4.
REGIONAL TOTAL	15.	0.	0.	4.	19.
SOUTH ATLANTIC					
ALA	11.	0.	0.	1.	12.
FLA	3.	0.	0.	0.	3.
GA	7.	0.	0.	1.	8.
KY	3.	0.	0.	2.	4.
MISS	1.	0.	0.	0.	1.
NC	5.	0.	0.	0.	6.
SC	4.	0.	1.	1.	5.
TENN	2.	0.	0.	0.	2.
REGIONAL TOTAL	35.	0.	1.	6.	42.
MIDWEST					
ILL	3.	0.	2.	1.	5.
IND	2.	0.	1.	0.	3.
MICH	5.	0.	0.	2.	7.
MINN	3.	0.	1.	0.	4.
OHIO	2.	0.	1.	1.	4.
WIS	5.	0.	2.	2.	8.
REGIONAL TOTAL	19.	0.	7.	6.	32.

```
                base case
            INDUSTRIAL BOILER FOSSIL FUEL DEMAND, 1995 (10**12 BTUS)
                    BOILERS BUILT SINCE PREVIOUS RUN YEAR

                          NAT. GAS     DIST.      RESID      COAL     TOTAL
SOUTHWEST
  ARK                         1.         0.         1.         1.        3.
  LA                         12.         0.         5.         3.       20.
  NM                          0.         0.         0.         0.        0.
  OKLA                        1.         0.         0.         0.        1.
  TX                         32.         0.         2.         5.       39.
REGIONAL TOTAL               47.         0.         8.         8.       63.

CENTRAL
  IOWA                        2.         0.         1.         2.        4.
  KS                          0.         0.         1.         0.        1.
  MO                          0.         0.         1.         0.        1.
  NB                          0.         0.         0.         0.        1.
REGIONAL TOTAL                3.         0.         2.         2.        7.

NORTH CENTRAL
  COL                         2.         0.         0.         0.        2.
  MONT                        0.         0.         0.         0.        0.
  ND                          0.         0.         0.         0.        1.
  SD                          0.         0.         0.         0.        0.
  UTAH                        0.         0.         0.         0.        0.
  WY                          1.         0.         0.         0.        1.
REGIONAL TOTAL                4.         0.         0.         0.        4.

WEST
  ARIZ                        1.         0.         0.         0.        1.
  CAL                        13.         0.         1.         2.       17.
  NV                          1.         0.         0.         0.        1.
REGIONAL TOTAL               15.         0.         1.         2.       19.

NORTHWEST
  ID                          1.         0.         0.         0.        1.
  OR                          2.         0.         0.         2.        3.
  WA                          2.         0.         0.         1.        3.
REGIONAL TOTAL                4.         0.         0.         3.        7.


LOWER  48 STATES            149.         0.        21.        35.      205.
```

base case
INDUSTRIAL BOILER FOSSIL FUEL DEMAND, 2000 (10**12 BTUS)
BOILERS BUILT SINCE PREVIOUS RUN YEAR

	NAT. GAS	DIST.	RESID	COAL	TOTAL
NEW ENGLAND					
CONN	2.	0.	0.	1.	3.
MAINE	4.	0.	0.	4.	7.
MASS	4.	0.	0.	2.	6.
NH	1.	0.	0.	0.	1.
RI	0.	0.	0.	0.	0.
VT	0.	0.	0.	0.	0.
REGIONAL TOTAL	10.	0.	0.	7.	17.
NEW YORK/NEW JERSEY					
NJ	3.	0.	0.	0.	4.
NY	13.	0.	0.	2.	14.
REGIONAL TOTAL	16.	0.	0.	2.	18.
MIDDLE ATLANTIC					
DEL	3.	0.	0.	0.	3.
MD/DC	3.	0.	0.	1.	4.
PA	7.	0.	1.	3.	10.
VA	17.	0.	0.	5.	22.
WV	8.	0.	0.	2.	11.
REGIONAL TOTAL	37.	0.	1.	12.	51.
SOUTH ATLANTIC					
ALA	17.	0.	1.	11.	28.
FLA	9.	0.	0.	1.	10.
GA	14.	0.	0.	2.	16.
KY	8.	0.	0.	5.	13.
MISS	3.	0.	0.	1.	4.
NC	11.	0.	0.	3.	14.
SC	8.	0.	2.	2.	12.
TENN	12.	0.	1.	0.	13.
REGIONAL TOTAL	80.	0.	4.	26.	110.
MIDWEST					
ILL	13.	0.	3.	3.	19.
IND	8.	0.	4.	2.	14.
MICH	13.	0.	0.	7.	20.
MINN	6.	0.	1.	1.	7.
OHIO	8.	0.	3.	3.	14.
WIS	8.	0.	3.	4.	14.
REGIONAL TOTAL	56.	0.	14.	19.	89.

base case

INDUSTRIAL BOILER FOSSIL FUEL DEMAND, 2000 (10**12 BTUS)

BOILERS BUILT SINCE PREVIOUS RUN YEAR

	NAT. GAS	DIST.	RESID	COAL	TOTAL
SOUTHWEST					
ARK	3.	0.	1.	0.	5.
LA	32.	0.	12.	9.	53.
NM	1.	0.	0.	0.	1.
OKLA	3.	0.	0.	0.	3.
TX	69.	0.	6.	28.	104.
REGIONAL TOTAL	108.	0.	20.	38.	166.
CENTRAL					
IOWA	10.	0.	1.	2.	12.
KS	1.	0.	2.	0.	4.
MO	2.	0.	1.	1.	4.
NB	2.	0.	0.	0.	2.
REGIONAL TOTAL	15.	0.	4.	3.	22.
NORTH CENTRAL					
COL	3.	0.	0.	1.	3.
MONT	1.	0.	0.	0.	1.
ND	1.	0.	0.	0.	1.
SD	0.	0.	0.	0.	0.
UTAH	2.	0.	0.	0.	2.
WY	4.	0.	0.	0.	4.
REGIONAL TOTAL	11.	0.	0.	1.	12.
WEST					
ARIZ	3.	0.	0.	0.	3.
CAL	29.	0.	2.	9.	40.
NV	1.	0.	0.	0.	1.
REGIONAL TOTAL	33.	0.	2.	9.	43.
NORTHWEST					
ID	3.	0.	0.	0.	3.
OR	3.	0.	0.	2.	5.
WA	7.	0.	0.	1.	8.
REGIONAL TOTAL	12.	0.	0.	4.	16.
LOWER 48 STATES	377.	0.	45.	121.	543.

base case
INDUSTRIAL BOILER FOSSIL FUEL DEMAND, 2010 (10**12 BTUS)
BOILERS BUILT SINCE PREVIOUS RUN YEAR

	NAT. GAS	DIST.	RESID	COAL	TOTAL
NEW ENGLAND					
CONN	3.	0.	0.	0.	4.
MAINE	5.	0.	0.	9.	14.
MASS	4.	0.	0.	3.	7.
NH	1.	0.	0.	1.	1.
RI	0.	0.	0.	0.	0.
VT	0.	0.	0.	0.	0.
REGIONAL TOTAL	12.	0.	0.	13.	26.
NEW YORK/NEW JERSEY					
NJ	3.	0.	0.	2.	5.
NY	9.	0.	0.	6.	15.
REGIONAL TOTAL	11.	0.	0.	8.	19.
MIDDLE ATLANTIC					
DEL	3.	0.	0.	2.	4.
MD/DC	5.	0.	0.	1.	6.
PA	7.	0.	1.	5.	13.
VA	20.	0.	0.	13.	33.
WV	12.	0.	0.	2.	14.
REGIONAL TOTAL	47.	0.	1.	23.	71.
SOUTH ATLANTIC					
ALA	25.	0.	2.	14.	41.
FLA	8.	0.	0.	6.	13.
GA	12.	0.	1.	13.	25.
KY	14.	0.	0.	5.	19.
MISS	4.	0.	0.	2.	6.
NC	11.	0.	0.	8.	19.
SC	8.	0.	3.	6.	17.
TENN	14.	0.	2.	5.	20.
REGIONAL TOTAL	97.	0.	7.	57.	161.
MIDWEST					
ILL	25.	0.	0.	9.	34.
IND	12.	0.	4.	4.	20.
MICH	12.	0.	0.	9.	21.
MINN	9.	0.	0.	2.	11.
OHIO	9.	0.	1.	7.	18.
WIS	12.	0.	0.	15.	26.
REGIONAL TOTAL	79.	0.	5.	46.	130.

```
              base case
         INDUSTRIAL BOILER FOSSIL FUEL DEMAND, 2010 (10**12 BTUS)
                 BOILERS BUILT SINCE PREVIOUS RUN YEAR

                         NAT. GAS      DIST.      RESID       COAL      TOTAL
SOUTHWEST
  ARK                          4.         0.         2.         2.         8.
  LA                          30.         0.        19.        33.        81.
  NM                           1.         0.         0.         0.         1.
  OKLA                         2.         0.         0.         1.         3.
  TX                          77.         0.         8.        44.       129.
REGIONAL TOTAL               114.         0.        28.        79.       222.

CENTRAL
  IOWA                        15.         0.         0.         4.        18.
  KS                           1.         0.         1.         1.         3.
  MO                           3.         0.         1.         1.         6.
  NB                           3.         0.         0.         0.         3.
REGIONAL TOTAL                22.         0.         2.         6.        30.

NORTH CENTRAL
  COL                          4.         0.         0.         1.         5.
  MONT                         1.         0.         0.         0.         1.
  ND                           2.         0.         0.         0.         2.
  SD                           0.         0.         0.         0.         1.
  UTAH                         1.         0.         0.         0.         1.
  WY                           2.         0.         0.         1.         4.
REGIONAL TOTAL                10.         0.         0.         2.        13.

WEST
  ARIZ                         2.         0.         0.         2.         4.
  CAL                         39.         0.         2.        12.        52.
  NV                           0.         0.         0.         0.         0.
REGIONAL TOTAL                41.         0.         2.        14.        56.

NORTHWEST
  ID                           4.         0.         0.         1.         5.
  OR                           3.         0.         0.         6.         9.
  WA                           4.         0.         0.         4.         9.
REGIONAL TOTAL                12.         0.         0.        11.        23.


LOWER  48 STATES             445.         0.        46.       260.       751.
```

```
              base case
          INDUSTRIAL BOILER FOSSIL FUEL DEMAND, 2020 (10**12 BTUS)
                  BOILERS BUILT SINCE PREVIOUS RUN YEAR

                         NAT. GAS      DIST.      RESID       COAL      TOTAL
NEW ENGLAND
  CONN                         2.         0.         0.         1.         2.
  MAINE                        5.         0.         0.         7.        12.
  MASS                         3.         0.         0.         2.         5.
  NH                           1.         0.         0.         0.         1.
  RI                           0.         0.         0.         0.         0.
  VT                           0.         0.         0.         0.         0.
REGIONAL TOTAL                12.         0.         0.         9.        21.

NEW YORK/NEW JERSEY
  NJ                           2.         0.         0.         2.         4.
  NY                           9.         0.         0.         2.        11.
REGIONAL TOTAL                11.         0.         0.         4.        15.

MIDDLE ATLANTIC
  DEL                          2.         0.         0.         1.         3.
  MD/DC                        2.         0.         0.         2.         4.
  PA                           6.         0.         1.         3.        10.
  VA                          11.         0.         0.        15.        26.
  WV                           6.         0.         0.         4.        10.
REGIONAL TOTAL                26.         0.         1.        26.        53.

SOUTH ATLANTIC
  ALA                         14.         0.         1.        16.        31.
  FLA                          5.         0.         0.         4.         9.
  GA                           9.         0.         0.        16.        26.
  KY                           6.         0.         0.         4.        11.
  MISS                         2.         0.         0.         1.         3.
  NC                           9.         0.         0.         7.        16.
  SC                           7.         0.         2.         4.        14.
  TENN                         9.         0.         2.         5.        15.
REGIONAL TOTAL                62.         0.         6.        57.       125.

MIDWEST
  ILL                         13.         0.         4.         8.        25.
  IND                          5.         0.         4.         4.        13.
  MICH                         9.         0.         0.        10.        19.
  MINN                         6.         0.         1.         2.         9.
  OHIO                         4.         0.         3.         6.        13.
  WIS                          7.         0.         4.        13.        24.
REGIONAL TOTAL                44.         0.        15.        43.       103.
```

```
            base case
        INDUSTRIAL BOILER FOSSIL FUEL DEMAND, 2020 (10**12 BTUS)
                BOILERS BUILT SINCE PREVIOUS RUN YEAR

                      NAT. GAS     DIST.     RESID      COAL     TOTAL
SOUTHWEST
  ARK                       4.        0.        1.        1.        6.
  LA                       14.        0.       12.       32.       58.
  NM                        0.        0.        0.        0.        0.
  OKLA                      1.        0.        0.        2.        3.
  TX                       46.        0.        4.       35.       86.
REGIONAL TOTAL             66.        0.       18.       70.      154.

CENTRAL
  IOWA                      8.        0.        0.        2.       10.
  KS                        0.        0.        2.        0.        2.
  MO                        2.        0.        1.        0.        3.
  NB                        2.        0.        0.        0.        2.
REGIONAL TOTAL             12.        0.        3.        2.       18.

NORTH CENTRAL
  COL                       3.        0.        0.        0.        3.
  MONT                      1.        0.        0.        0.        1.
  ND                        1.        0.        0.        0.        1.
  SD                        0.        0.        0.        0.        0.
  UTAH                      0.        0.        0.        0.        0.
  WY                        1.        0.        0.        0.        1.
REGIONAL TOTAL              6.        0.        0.        0.        6.

WEST
  ARIZ                      2.        0.        0.        0.        2.
  CAL                      27.        0.        2.       13.       41.
  NV                        0.        0.        0.        0.        0.
REGIONAL TOTAL             29.        0.        2.       13.       43.

NORTHWEST
  ID                        2.        0.        0.        1.        3.
  OR                        4.        0.        0.        4.        8.
  WA                        4.        0.        0.        3.        7.
REGIONAL TOTAL             11.        0.        0.        8.       19.


LOWER  48 STATES          279.        0.       45.      234.      558.
```

```
            base case
        INDUSTRIAL BOILER FOSSIL FUEL DEMAND, 2030 (10**12 BTUS)
                BOILERS BUILT SINCE PREVIOUS RUN YEAR

                          NAT. GAS     DIST.     RESID      COAL     TOTAL
NEW ENGLAND
  CONN                          2.        0.        0.        2.        4.
  MAINE                         7.        0.        0.       11.       18.
  MASS                          5.        0.        0.        3.        8.
  NH                            2.        0.        0.        1.        2.
  RI                            0.        0.        0.        0.        0.
  VT                            0.        0.        0.        0.        0.
REGIONAL TOTAL                 16.        0.        0.       17.       33.

NEW YORK/NEW JERSEY
  NJ                            5.        0.        0.        2.        7.
  NY                           15.        0.        0.        8.       23.
REGIONAL TOTAL                 20.        0.        0.       10.       29.

MIDDLE ATLANTIC
  DEL                           3.        0.        0.        1.        4.
  MD/DC                         3.        0.        0.        3.        6.
  PA                           11.        0.        4.        5.       20.
  VA                           18.        0.        1.       20.       39.
  WV                           15.        0.        0.        5.       20.
REGIONAL TOTAL                 51.        0.        4.       33.       89.

SOUTH ATLANTIC
  ALA                          17.        0.        2.       20.       39.
  FLA                           6.        0.        0.        8.       14.
  GA                           13.        0.        0.       18.       31.
  KY                            8.        0.        0.        8.       16.
  MISS                          3.        0.        0.        2.        5.
  NC                           13.        0.        0.        9.       22.
  SC                            4.        0.        5.       11.       19.
  TENN                         11.        0.        4.       10.       25.
REGIONAL TOTAL                 75.        0.       10.       86.      172.

MIDWEST
  ILL                          15.        0.        6.       15.       36.
  IND                           7.        0.        6.        8.       21.
  MICH                          8.        0.        0.       22.       30.
  MINN                          7.        0.        1.        4.       12.
  OHIO                          5.        0.        5.       11.       22.
  WIS                           7.        0.        4.       20.       31.
REGIONAL TOTAL                 50.        0.       23.       80.      153.
```

```
         base case
     INDUSTRIAL BOILER FOSSIL FUEL DEMAND, 2030 (10**12 BTUS)
             BOILERS BUILT SINCE PREVIOUS RUN YEAR

                         NAT. GAS     DIST.      RESID       COAL      TOTAL
SOUTHWEST
  ARK                         4.        0.         1.         3.         8.
  LA                         33.        0.        18.        29.        80.
  NM                          1.        0.         0.         0.         1.
  OKLA                        2.        0.         0.         2.         4.
  TX                         68.        0.         8.        66.       141.
REGIONAL TOTAL              108.        0.        27.       100.       235.

CENTRAL
  IOWA                       13.        0.         1.         4.        18.
  KS                          1.        0.         3.         1.         4.
  MO                          2.        0.         2.         2.         6.
  NB                          2.        0.         0.         1.         2.
REGIONAL TOTAL               17.        0.         6.         8.        31.

NORTH CENTRAL
  COL                         2.        0.         0.         1.         4.
  MONT                        1.        0.         0.         0.         1.
  ND                          1.        0.         0.         0.         1.
  SD                          0.        0.         0.         0.         0.
  UTAH                        1.        0.         0.         0.         2.
  WY                          5.        0.         0.         2.         7.
REGIONAL TOTAL               11.        0.         0.         4.        15.

WEST
  ARIZ                        2.        0.         0.         2.         4.
  CAL                        36.        0.         2.        13.        51.
  NV                          0.        0.         0.         0.         0.
REGIONAL TOTAL               39.        0.         2.        15.        56.

NORTHWEST
  ID                          3.        0.         0.         0.         4.
  OR                          5.        0.         0.         6.        11.
  WA                          6.        0.         0.         4.        10.
REGIONAL TOTAL               14.        0.         0.        11.        25.


LOWER  48 STATES            402.        0.        72.       364.       838.
```

```
              base case
       INDUSTRIAL BOILER FOSSIL FUEL DEMAND, 1990 (NUMBER OF BOILERS)
               BOILERS BUILT SINCE PREVIOUS RUN YEAR

                       NAT. GAS      DIST.     RESID       COAL      TOTAL
WITHOUT COAL EXPERIENCE
    < 100                 1470.         0.      760.        59.      2289.
  100-250                  293.         0.       97.         9.       399.
    > 250                   75.         0.       29.         2.       106.
  ALL SIZES               1838.         0.      886.        70.      2794.
WITH COAL EXPERIENCE
    < 100                   16.         0.        6.         1.        23.
  100-250                   83.         0.       34.        56.       173.
    > 250                   39.         0.        7.        23.        69.
  ALL SIZES                138.         0.       47.        80.       265.
ALL NEW BOILERS
    < 100                 1486.         0.      766.        60.      2312.
  100-250                  376.         0.      131.        65.       572.
    > 250                  114.         0.       36.        25.       175.
  ALL SIZES               1976.         0.      933.       150.      3063.
```

```
              base case
       INDUSTRIAL BOILER FOSSIL FUEL DEMAND, 1995 (NUMBER OF BOILERS)
               BOILERS BUILT SINCE PREVIOUS RUN YEAR

                       NAT. GAS      DIST.     RESID       COAL      TOTAL
WITHOUT COAL EXPERIENCE
    < 100                  467.         0.      137.        17.       621.
  100-250                   82.         0.        0.         4.        86.
    > 250                   19.         0.        0.         1.        20.
  ALL SIZES                568.         0.      137.        22.       727.
WITH COAL EXPERIENCE
    < 100                   50.         0.       16.         7.        73.
  100-250                   31.         0.        0.        28.        59.
    > 250                   11.         0.        0.        14.        25.
  ALL SIZES                 92.         0.       16.        49.       157.
ALL NEW BOILERS
    < 100                  517.         0.      153.        24.       694.
  100-250                  113.         0.        0.        32.       145.
    > 250                   30.         0.        0.        15.        45.
  ALL SIZES                660.         0.      153.        71.       884.
```

```
              base case
       INDUSTRIAL BOILER FOSSIL FUEL DEMAND, 2000 (NUMBER OF BOILERS)
               BOILERS BUILT SINCE PREVIOUS RUN YEAR

                       NAT. GAS      DIST.     RESID       COAL      TOTAL
WITHOUT COAL EXPERIENCE
    < 100                 1048.         0.      265.        41.      1354.
  100-250                  227.         0.        0.         8.       235.
    > 250                   37.         0.        0.         1.        38.
  ALL SIZES               1312.         0.      265.        50.      1627.
WITH COAL EXPERIENCE
    < 100                  109.         0.       18.        11.       138.
  100-250                   54.         0.        0.        76.       130.
    > 250                   21.         0.        0.        45.        66.
  ALL SIZES                184.         0.       18.       132.       334.
ALL NEW BOILERS
    < 100                 1157.         0.      283.        52.      1492.
  100-250                  281.         0.        0.        84.       365.
    > 250                   58.         0.        0.        46.       104.
  ALL SIZES               1496.         0.      283.       182.      1966.
```

```
                base case
         INDUSTRIAL BOILER FOSSIL FUEL DEMAND, 2010 (NUMBER OF BOILERS)
                 BOILERS BUILT SINCE PREVIOUS RUN YEAR

                      NAT. GAS       DIST.       RESID        COAL       TOTAL
WITHOUT COAL EXPERIENCE
    < 100               1310.          0.         243.          56.       1609.
  100-250                246.          0.           0.          28.        274.
    > 250                 59.          0.           0.          22.         81.
  ALL SIZES             1615.          0.         243.         106.       1965.
WITH COAL EXPERIENCE
    < 100                163.          0.          18.          18.        199.
  100-250                 62.          0.           0.         146.        208.
    > 250                  8.          0.           0.          72.         80.
  ALL SIZES              233.          0.          18.         236.        487.
ALL NEW BOILERS
    < 100               1473.          0.         261.          74.       1808.
  100-250                308.          0.           0.         174.        482.
    > 250                 67.          0.           0.          94.        161.
  ALL SIZES             1848.          0.         261.         342.       2456.
```

```
                base case
         INDUSTRIAL BOILER FOSSIL FUEL DEMAND, 2020 (NUMBER OF BOILERS)
                 BOILERS BUILT SINCE PREVIOUS RUN YEAR

                      NAT. GAS       DIST.       RESID        COAL       TOTAL
WITHOUT COAL EXPERIENCE
    < 100                851.          0.         245.          50.       1146.
  100-250                177.          0.           0.          33.        210.
    > 250                 36.          0.           0.          15.         51.
  ALL SIZES             1064.          0.         245.          98.       1408.
WITH COAL EXPERIENCE
    < 100                124.          0.          35.          16.        175.
  100-250                 30.          0.           0.         112.        142.
    > 250                 11.          0.           0.          67.         78.
  ALL SIZES              165.          0.          35.         195.        395.
ALL NEW BOILERS
    < 100                975.          0.         280.          66.       1321.
  100-250                207.          0.           0.         145.        352.
    > 250                 47.          0.           0.          82.        129.
  ALL SIZES             1229.          0.         280.         293.       1803.
```

```
                base case
         INDUSTRIAL BOILER FOSSIL FUEL DEMAND, 2030 (NUMBER OF BOILERS)
                 BOILERS BUILT SINCE PREVIOUS RUN YEAR

                      NAT. GAS       DIST.       RESID        COAL       TOTAL
WITHOUT COAL EXPERIENCE
    < 100               1145.          0.         390.          68.       1603.
  100-250                269.          0.           0.          39.        308.
    > 250                 39.          0.           0.          42.         81.
  ALL SIZES             1453.          0.         390.         149.       1992.
WITH COAL EXPERIENCE
    < 100                168.          0.          65.          34.        267.
  100-250                 36.          0.           0.         171.        207.
    > 250                  4.          0.           0.          94.         98.
  ALL SIZES              208.          0.          65.         299.        572.
ALL NEW BOILERS
    < 100               1313.          0.         455.         102.       1870.
  100-250                305.          0.           0.         210.        515.
    > 250                 43.          0.           0.         136.        179.
  ALL SIZES             1661.          0.         455.         448.       2564.
```

Appendix B:

PROMPT Model Runs -- Computer Printouts on Emissions for the NAPAP Reference-Case Scenario

Base Case (SC0)

SO2 EMISSIONS
(000 SHORT TONS)

INCLUDES SMELTERS AND SULFUR PROCESSING
CORRESPONDS WITH OUTEMISR.DAT EMISSIONS

STATE	1985	1990	1995	2000	2010	2020	2030
AL	122.	136.	131.	136.	138.	141.	147.
AZ	574.	180.	179.	179.	180.	180.	180.
AR	26.	17.	17.	18.	20.	21.	22.
CA	93.	186.	181.	184.	240.	251.	276.
CO	6.	9.	10.	10.	9.	10.	11.
CT	2.	2.	2.	3.	4.	5.	6.
DE	39.	38.	36.	38.	41.	43.	46.
FL	60.	64.	63.	65.	68.	70.	72.
GA	45.	46.	46.	49.	52.	56.	62.
ID	30.	42.	42.	42.	41.	42.	43.
IL	218.	201.	193.	204.	204.	205.	212.
IN	98.	92.	86.	91.	85.	80.	81.
IA	6.	2.	2.	3.	3.	4.	5.
KS	35.	19.	19.	21.	22.	24.	27.
KY	41.	53.	49.	51.	51.	53.	56.
LA	231.	171.	163.	170.	185.	186.	191.
ME	10.	26.	27.	30.	38.	43.	51.
MD	28.	34.	31.	33.	35.	37.	40.
MA	5.	7.	7.	7.	11.	14.	17.
MI	58.	107.	106.	112.	115.	119.	128.
MN	23.	20.	20.	20.	20.	20.	21.
MS	61.	63.	61.	63.	65.	68.	72.
MO	162.	87.	85.	100.	106.	111.	122.
MT	61.	41.	41.	42.	40.	39.	38.
NE	11.	4.	4.	5.	6.	7.	8.
NV	4.	10.	9.	9.	12.	12.	13.
NH	0.	1.	1.	1.	1.	1.	1.
NJ	30.	38.	37.	39.	46.	50.	57.
NM	176.	166.	168.	174.	176.	178.	182.
NY	27.	68.	60.	60.	65.	66.	72.
NC	38.	46.	44.	47.	49.	52.	56.
ND	68.	66.	63.	65.	63.	60.	58.
OH	156.	152.	145.	154.	151.	149.	154.
OK	19.	33.	31.	31.	30.	29.	30.
OR	5.	9.	10.	11.	11.	12.	13.
PA	100.	76.	73.	74.	76.	82.	95.
RI	0.	0.	0.	0.	0.	0.	0.
SC	33.	48.	44.	46.	48.	50.	53.
SD	3.	5.	5.	6.	6.	7.	8.
TN	62.	66.	63.	67.	70.	74.	80.
TX	711.	549.	535.	560.	610.	618.	642.
UT	31.	79.	78.	89.	88.	87.	87.
VT	1.	1.	1.	1.	2.	2.	3.
VA	21.	20.	20.	21.	22.	23.	24.
WA	14.	25.	25.	27.	29.	30.	33.
WV	66.	69.	66.	69.	75.	79.	88.
WI	25.	30.	30.	32.	34.	35.	38.
WY	54.	56.	56.	57.	57.	56.	58.
US	3687.	3262.	3164.	3315.	3500.	3580.	3776.

Base Case (SC0)

SO2 EMISSIONS
(000 SHORT TONS)

EXCLUDES SMELTERS AND SULFUR PROCESSING
CORRESPONDS WITH OUTESIM.DAT EMISSIONS

STATE	1985	1990	1995	2000	2010	2020	2030
AL	62.	80.	76.	80.	82.	86.	92.
AZ	2.	13.	11.	11.	12.	12.	13.
AR	19.	11.	10.	11.	14.	14.	15.
CA	88.	181.	176.	179.	235.	247.	272.
CO	5.	9.	10.	10.	9.	10.	11.
CT	2.	2.	2.	3.	4.	5.	6.
DE	37.	36.	34.	36.	39.	41.	44.
FL	27.	32.	31.	33.	36.	38.	41.
GA	42.	45.	44.	48.	51.	55.	60.
ID	21.	34.	33.	34.	33.	33.	35.
IL	198.	181.	173.	184.	184.	185.	192.
IN	88.	89.	83.	87.	81.	77.	77.
IA	6.	2.	2.	3.	3.	4.	5.
KS	33.	17.	17.	19.	20.	22.	25.
KY	39.	51.	46.	48.	48.	50.	53.
LA	182.	123.	115.	122.	137.	138.	143.
ME	10.	26.	27.	30.	38.	43.	51.
MD	28.	34.	31.	33.	35.	37.	40.
MA	5.	6.	6.	7.	11.	13.	17.
MI	58.	61.	60.	66.	69.	73.	82.
MN	20.	18.	17.	18.	18.	18.	18.
MS	40.	43.	40.	43.	45.	48.	52.
MO	96.	63.	62.	69.	75.	80.	91.
MT	31.	33.	33.	34.	32.	30.	30.
NE	11.	4.	4.	5.	6.	7.	8.
NV	4.	10.	9.	9.	12.	12.	13.
NH	0.	1.	1.	1.	1.	1.	1.
NJ	26.	34.	33.	35.	42.	46.	53.
NM	10.	9.	10.	12.	13.	16.	19.
NY	26.	68.	60.	60.	64.	66.	71.
NC	34.	42.	40.	43.	45.	48.	52.
ND	60.	58.	55.	57.	55.	52.	50.
OH	151.	150.	143.	152.	149.	147.	152.
OK	17.	23.	21.	21.	19.	19.	20.
OR	5.	9.	10.	11.	11.	12.	13.
PA	93.	75.	72.	73.	76.	81.	94.
RI	0.	0.	0.	0.	0.	0.	0.
SC	32.	48.	44.	46.	48.	50.	53.
SD	3.	5.	5.	6.	6.	7.	8.
TN	55.	65.	62.	65.	68.	72.	79.
TX	482.	303.	289.	312.	362.	370.	394.
UT	22.	22.	22.	22.	21.	20.	20.
VT	1.	1.	1.	1.	2.	2.	3.
VA	17.	17.	16.	17.	19.	19.	21.
WA	14.	25.	25.	27.	29.	30.	33.
WV	66.	69.	66.	69.	75.	79.	88.
WI	24.	29.	29.	31.	33.	34.	37.
WY	34.	37.	36.	38.	37.	37.	38.
US	2325.	2292.	2194.	2320.	2505.	2584.	2781.

Base Case (SC0)

NOX EMISSIONS
(000 SHORT TONS)

INCLUDES PIPELINES
CORRESPONDS WITH OUTEMISR.DAT EMISSIONS

STATE	1985	1990	1995	2000	2010	2020	2030
AL	79.	86.	84.	89.	92.	96.	102.
AZ	44.	43.	43.	44.	45.	48.	52.
AR	76.	63.	60.	60.	57.	56.	55.
CA	278.	283.	284.	310.	334.	373.	432.
CO	56.	50.	49.	50.	49.	48.	48.
CT	14.	19.	19.	21.	22.	23.	24.
DE	11.	13.	12.	11.	12.	11.	10.
FL	67.	76.	74.	80.	85.	89.	96.
GA	63.	67.	65.	70.	73.	76.	82.
ID	16.	15.	15.	15.	16.	16.	16.
IL	146.	157.	152.	164.	168.	170.	179.
IN	108.	114.	110.	118.	119.	119.	124.
IA	53.	36.	33.	35.	34.	34.	35.
KS	138.	124.	123.	125.	125.	127.	130.
KY	75.	79.	77.	81.	83.	86.	90.
LA	332.	304.	300.	306.	307.	308.	312.
ME	1.	10.	11.	13.	17.	22.	29.
MD	58.	62.	58.	59.	60.	57.	53.
MA	16.	22.	21.	23.	24.	25.	26.
MI	88.	93.	91.	97.	98.	99.	104.
MN	51.	51.	48.	51.	49.	47.	46.
MS	88.	90.	89.	94.	97.	101.	108.
MO	76.	54.	52.	58.	59.	64.	70.
MT	64.	50.	47.	48.	46.	43.	42.
NE	43.	28.	27.	28.	27.	28.	29.
NV	3.	3.	3.	3.	4.	4.	5.
NH	1.	2.	2.	2.	3.	4.	6.
NJ	41.	54.	53.	60.	69.	78.	90.
NM	110.	108.	109.	114.	117.	120.	124.
NY	47.	81.	75.	76.	72.	66.	57.
NC	50.	51.	50.	53.	55.	58.	62.
ND	41.	31.	30.	30.	29.	27.	26.
OH	103.	107.	104.	110.	111.	111.	114.
OK	157.	148.	146.	148.	147.	147.	149.
OR	30.	30.	30.	32.	32.	32.	33.
PA	104.	117.	115.	121.	128.	135.	147.
RI	1.	2.	2.	2.	3.	4.	6.
SC	29.	37.	35.	38.	40.	41.	45.
SD	14.	11.	11.	11.	11.	10.	10.
TN	80.	87.	85.	91.	95.	100.	108.
TX	1129.	1019.	1004.	1037.	1047.	1055.	1079.
UT	41.	36.	35.	35.	35.	34.	34.
VT	7.	10.	10.	10.	10.	11.	10.
VA	48.	54.	51.	52.	54.	54.	53.
WA	48.	47.	47.	51.	52.	52.	55.
WV	76.	82.	77.	78.	79.	75.	71.
WI	66.	69.	65.	70.	69.	68.	69.
WY	76.	69.	68.	68.	67.	66.	65.
US	4342.	4243.	4151.	4343.	4425.	4519.	4713.

Base Case (SC0)

NOX EMISSIONS
(000 SHORT TONS)

EXCLUDES PIPELINES
CORRESPONDS WITH OUTESIM.DAT EMISSIONS

STATE	1985	1990	1995	2000	2010	2020	2030
AL	57.	63.	61.	66.	70.	74.	80.
AZ	21.	20.	20.	22.	22.	25.	30.
AR	54.	40.	37.	37.	35.	33.	33.
CA	227.	232.	234.	260.	283.	322.	382.
CO	30.	24.	23.	24.	23.	22.	22.
CT	13.	19.	19.	20.	21.	22.	23.
DE	11.	13.	12.	11.	12.	11.	10.
FL	58.	67.	65.	71.	76.	80.	87.
GA	58.	62.	60.	65.	67.	71.	77.
ID	13.	11.	11.	12.	12.	12.	13.
IL	130.	141.	136.	148.	152.	154.	163.
IN	95.	102.	97.	105.	107.	107.	111.
IA	44.	27.	24.	26.	25.	25.	26.
KS	45.	31.	29.	32.	31.	33.	36.
KY	37.	41.	40.	43.	45.	48.	52.
LA	142.	114.	109.	116.	116.	117.	121.
ME	1.	10.	11.	13.	17.	22.	29.
MD	55.	59.	56.	56.	57.	54.	50.
MA	14.	20.	19.	21.	22.	23.	24.
MI	64.	68.	66.	72.	73.	75.	79.
MN	45.	45.	43.	45.	44.	41.	40.
MS	57.	58.	57.	62.	66.	70.	76.
MO	71.	49.	47.	53.	54.	59.	65.
MT	60.	45.	43.	44.	42.	39.	38.
NE	37.	23.	21.	23.	21.	22.	23.
NV	2.	3.	3.	3.	3.	4.	4.
NH	0.	1.	1.	1.	2.	3.	5.
NJ	41.	54.	53.	60.	69.	78.	90.
NM	25.	23.	24.	28.	32.	34.	39.
NY	41.	75.	69.	70.	66.	60.	51.
NC	44.	45.	44.	47.	49.	52.	56.
ND	33.	23.	22.	22.	21.	19.	18.
OH	81.	86.	82.	89.	89.	89.	93.
OK	53.	44.	43.	44.	44.	44.	46.
OR	25.	24.	24.	26.	26.	26.	27.
PA	58.	71.	70.	75.	83.	90.	101.
RI	0.	1.	1.	2.	3.	4.	6.
SC	26.	34.	32.	35.	37.	38.	42.
SD	14.	11.	10.	11.	10.	10.	10.
TN	69.	76.	74.	80.	84.	89.	96.
TX	587.	477.	462.	495.	504.	513.	537.
UT	27.	22.	21.	22.	21.	20.	20.
VT	7.	10.	10.	10.	10.	11.	10.
VA	43.	49.	46.	47.	49.	49.	48.
WA	46.	45.	45.	49.	50.	51.	53.
WV	58.	64.	59.	60.	61.	57.	53.
WI	63.	65.	62.	66.	65.	64.	65.
WY	26.	19.	18.	18.	17.	16.	15.
US	2806.	2706.	2614.	2806.	2888.	2982.	3176.